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SUPPLEMENT

TO THE

ENCYCLOPÆDIA.

AARONSBURG, a poſt town in Northumberland county, Pennſylvania, lies near the head of Penn's creek, it is chiefly a German ſettlement, about 30 miles weſterly from Lewiſburg and 40 W. by N. from Sunbury, 160 miles W. N. W. from Philadelphia.—*Morse.*

ABACISCUS, in architecture, the ſame with Abacus; for which, ſee *Encyclopædia.*

ABACOOCHEE, or *Cooſee,* a large river riſing in the S. W. Territory, paſſing into Georgia, through the Cherokee into the Creek country, where it unites with the Oakfuſkee, and forms the Alibama.—*Morse.*

ABATIS, or Abattis, is, in military language, the name of a kind of retrenchment made of felled trees. When the emergency is ſudden, the trees are merely laid lengthwiſe beſide each other, with their branches pointed towards the enemy, to prevent his approach, whilſt the trunks ſerve as a breaſtwork before thoſe by whom the abatis is raiſed. When the abatis is meant for the defence of a paſs or entrance, the boughs of the trees are generally ſtripped of their leaves and pointed; the trunks are planted in the ground; and the boughs are interwoven with each other. It is needleſs to add that the cloſer the trees are laid or planted together, the more ſecure is the defence which they afford; and if, when they are planted, a ſmall ditch be dug towards the enemy, and the earth thrown up properly againſt the lower part of the abatis, it will be very difficult to paſs it if well defended.—*Simes's Military Guide.*

ABBEVILLE *County,* in Ninety-ſix diſtrict, S. Carolina, bounded on the N. E. by the Saluda, and on the S. W. by the Savannah, is 35 miles in length and 21 in breadth; contains 9197 inhabitants, including 1665 ſlaves. The ſoil is rich and well watered. —*Morse.*

ABBREVIATION of fractions, in arithmetic and algebra, is the reducing of them to lower terms; which is done by dividing the numerator and denominator by ſome number or quantity which will divide both without leaving a remainder of either.

ABERRATION, in optics (in Encycl.), refers the reader to the article Optics, n° 17, 136, 173. It ſhould have referred him to Optics, n° 17, and 251—256.

Aberration of the Viſual Ray, is a phenomenon, of which, though ſome account of it has been given in the Encyclopædia (ſee Aberration, in aſtronomy; and the article Astronomy, n° 337.), one of the moſt candid of our correſpondents requires a fuller explanation. If ſuch an explanation be requiſite to him, it muſt be much more ſo to many others; and we know not where to find, or how to deviſe, one which would be more ſatisfactory, or more familiar, than the following by Dr. Hutton.

"This effect (ſays he) may be explained and familiarized by the motion of a line parallel to itſelf, much after the manner that the compoſition and reſolution of forces are explained. If light have a progreſſive motion, let the proportion of its velocity to that of the earth in her orbit be as the line BC to the line AC; then, by the compoſition of theſe two motions, the particle of light will ſeem to deſcribe the line BA or DC, inſtead of its real courſe BC; and will appear in the direction AB or CD, inſtead of its true direction CB. So that if AB repreſent a tube, carried with a parallel motion by an obſerver along the line AC, in the time that a particle of light would move over the ſpace BC, the different places of the tube being AB, *ab*, *cd*, CD; and when the eye, or end of the tube, is at A, let a particle of light enter the other end at B; then when the tube is at *ab*, the particle of light will be at *e*, exactly in the axis of the tube; and when the tube is at *cd*, the particle of light will arrive at *f*, ſtill in the axis of the tube; and, laſtly, when the tube arrives at CD, the particle of light will arrive at the eye or point C, and conſequently will appear to come in the direction DC of the tube, inſtead of the true direction BC: and ſo on, one particle ſucceeding another, and forming a continued ſtream or ray of light in the apparent direction DC. So that the apparent angle made by the ray of light with the line AE is the angle DCE, inſtead of the true angle BCE; and the difference BCD, or ABC, is the quantity of the aberration."

Plate II. fig. 1.

Aberration of the Planets, is equal to their geocentric motion, or, in other words, to the ſpace which each appears to move as ſeen from the earth, during the time that light employs in paſſing from the planet to the eye of the obſerver. Thus the ſun's aberration in longitude is conſtantly 20″, that being the ſpace actually moved by the earth; but apparently by the ſun in 8 minutes and 7 ſeconds, the time in which light paſſes from the ſun to the earth. If then the diſtance of any planet from the earth be known, the time which light employs in paſſing from the planet to the earth muſt likewiſe be known; for as the diſtance of the ſun is to the diſtance of the planet, ſo is 8 minutes and 7 ſeconds to that time; and the planet's geocentric motion in that time is its aberration, whether it be in longitude, latitude, right aſcenſion, or declination. See ASTRONOMY in this Supplement.

ABINGDON, a town at the head of the tide waters of Buſh river, Harford county, Maryland; 12 miles S. W. from Havre-de-Grace, and 20 N. E. from Baltimore.—Cokeſbury College, inſtituted by the Methodiſts, in 1785, is in this town.—*Morse.*

ABINGDON, the chief town of Waſhington county, Virginia, contained but about 20 houſes in 1788, in 1796 upwards of 150. It is about 145 miles from Campbell's ſtation, near Holſton; 260 from Richmond, in Virginia, in a direct line, and 310 as the road runs, bearing a little to the S. of W. Lat. 36. 30. N. The air is pure and ſalubrious, with plenty of excellent water.—*ib.*

ABINGTON, a townſhip in Plymouth county, Maſſachuſetts; 22 miles ſouth-eaſterly from Boſton, and contains 1453 inhabitants.—*ib.*

ABINGTON, a pariſh in the town of Pomfret, in Connecticut.—*ib.*

ABINGTON, a village in Pennſylvania, 12 miles N. of Philadelphia.—*ib.*

ABIPONES, an Indian nation in Paraguay, S. America.—*ib.*

ABITIBBI, a ſmall lake in Upper Canada; on the S. ſide of which is a ſettlement called Frederick, which laſt lies in N. lat. 49. W. long. 79. 40. Alſo the name of a river which runs N. and joins Mooſe river, near its mouth at James's bay.—*ib.*

ABITIBIS, a lake N. of Nipiſſing lake, the N. E. boundary of Canada, in New South Wales; it has communication with James's bay, near Mooſe Fort. N. lat. 59. 3. W. long. 78. 5.—*ib.*

ABOAB, ceſſes levied, in India, under different denominations, beyond the ſtandard rent.

ABSCISS, ABSCISSE, or *Abſciſſa*, is a part cut off from a ſtraight line, and terminated at ſome certain point by an ordinate to a curve; as AP (fig. 2.), or BP (fig. 3.) The abſciſs may commence either at the vertex of the curve, or at any other fixed point; and it may be taken either upon the axis or upon the diameter of the curve, or upon any other line drawn in a given poſition. Hence there are on the ſame given line or diameter an infinite number of variable abſciſſes, terminated all at one end by the ſame fixed point. In the common parabola (fig. 4.), each ordinate PQ has but one abſciſs AP. In the elipſe or circle (fig. 2.), the ordinate has two abſciſſes lying on the oppoſite ſides of it. In general, to each ordinate a line of the ſecond kind, or a curve of the firſt kind, may have two abſciſſes; a line of the third order, three; a line of the fourth order, four; and ſo on.

Plate II.

ABSECON *Beach*, on the coaſt of New-Jerſey, 16 miles S. W. from Little Egg Harbor.—*Morse.*

ABSORPTION, in ANATOMY and PHYSIOLOGY, has been ſufficiently explained under theſe articles in the Encyclopædia; but there is another abſorbing power poſſeſſed by different ſubſtances, which is worthy of attention, becauſe it is only by our knowledge of it that we can adapt our clothing to the various climates of the earth. The power to which we allude is that of different ſubſtances: ſuch as wool, cotton, ſilk, and linen, to abſorb or attract moiſture from the atmoſphere. On this ſubject the reader will find ſome very inſtructive experiments detailed (in Encycl.), where perhaps he may not have looked for them, under the title FLANEL.

ABSURDUM, a term made uſe of by mathematicians when they demonſtrate any truth, by ſhowing that its contrary is impoſſible, or involves an abſurdity. Thus, Euclid demonſtrates the truth of the fourth propoſition of the firſt book of his Elements, by ſhowing that its contrary implies this obvious abſurdity—"that two ſtraight lines may incloſe a ſpace."

This mode of demonſtration is called *reductio ad abſurdum*, and is every whit as concluſive as the direct method; becauſe the contrary of every falſehood muſt be truth, and of every truth, falſehood.

The young geometrician, however, does not, we believe, feel himſelf ſo perfectly ſatisfied with a demonſtration of this kind, as with thoſe which, proceeding from a few ſelf-evident truths, conduct him directly, by neceſſary conſequences, to the truth of the propoſition to be proved. The reaſon is, that he has not yet learned to diſtinguiſh accurately between the words *falſe* and *impoſſible*, *different* and *contrary*. Many *different* aſſertions may be made relating to the ſame thing, and yet be all true or all falſe; but it is impoſſible to make two aſſertions directly *contrary* to each other, of which the one ſhall not be true and the other falſe. Thus, "ſnow is white," "ſnow is cold," are different aſſertions relating to the ſame thing, and both true; as, "ſnow is black," "ſnow is red," are both falſe: but let it be remembered, that of the firſt and ſecond, and of the third and fourth of theſe aſſertions, neither is directly *contrary* to the other; nor is any one of them, abſtractly conſidered, *impoſſible*, or ſuch as a blind man, who had never felt nor heard of ſnow, might not believe upon ordinary teſtimony. But were all the men in Europe to tell a native of the interior parts of Africa that ſnow is a thing at once *white and not white, cold and not cold*, the woolly-headed ſavage would know as well as the moſt ſagacious philoſopher, that of theſe *contrary* aſſertions the one *muſt be true* and the other *muſt be falſe*. Juſt ſo it is with reſpect to Euclid's fourth propoſition. Had he proved its truth by ſhowing that its contrary involves this propoſition, that "the diagonal of a ſquare is commenſurate with its ſide," the ſkilful geometrician would indeed have admitted the demonſtration, becauſe he knows well that the diagonal of a ſquare is *not* commenſurate with its ſide; but the tyro in geometry would have been no wiſer than before. He knew from the beginning, that the propoſition and its contrary cannot both be true; but which of them is true, and which falſe, ſuch a demonſtration could not have taught him, becauſe he is ignorant of the incommenſurability of the diagonal and ſide of a ſquare. No man, however, is ignorant, that two ſtraight lines cannot incloſe a ſpace; and ſince Euclid ſhows that the contrary of his propoſition implies this abſurdity, no man of common ſenſe can entertain a doubt but that the propoſition itſelf muſt be true.

ACCELERATED MOTION. } See (Encycl.) ACCELERATION; and MECHANICS,
ACCELERATING FORCE. }

MECHANICS, Sect. VI.—and (this Supplement) DYNAMICS.

ACCOMACK *County*, in Virginia, is ſituated on a peninſula, bounded N. by Maryland, E. by the ocean, and on the W. by Cheſapeak bay, and contains 13,959 inhabitants, including 4262 ſlaves.—*Morſe.*

ACQUACKNACK, or *Acquakinunk*, a town on the W. ſide of Paſſaic river, in Eſſex county, New-Jerſey, 10 miles N. of Newark, and 17 N. W. from New-York.—*ib.*

ACTION is a term which has been ſufficiently explained in the Encyclopædia; but ſince that article was written, queſtions have been agitated reſpecting *agents*, *agency*, and *action*, which, as they have employed ſome of the moſt eminent philoſophers of the age, and are connected with the deareſt intereſts of man, are certainly entitled to notice in this place.

It is the opinion of Dr. Reid, and we have adopted it (ſee METAPHYSICS, n° 109, &c. Encycl.), that no being can be an *agent*, or perform an *action*, in the proper ſenſe of the word, which does not poſſeſs, in ſome degree, the powers of will and underſtanding. If this opinion be juſt, it is obvious, that what are called the powers of nature, ſuch as *impulſe*, *attraction*, *repulſion*, *elaſticity*, &c. are not, ſtrictly ſpeaking, *powers* or *cauſes*, but the effects of the agency of ſome active and intelligent being; and that *phyſical cauſes*, to make uſe of common language, are nothing more than *laws* or *rules*, according to which the *agent* produces the effect.

This doctrine has been controverted by a writer whoſe acuteneſs is equalled only by his virtues; and we ſhall conſider ſome of his objections to it in another place (ſee CAUSE): but a queſtion of a different kind falls under our preſent conſideration; and perhaps the anſwer which we muſt give to it, may go far to remove the objections to which we allude.

Can an agent operate where, either by itſelf or by an inſtrument, it is not preſent? We think not; becauſe agency, or the exertion of power, muſt be the agency of ſomething. The conſtitution of the human mind compels us to attribute every action to ſome *being*; but if a being could act in *one* place from which it is abſent, it might do the ſame in a ſecond, in a third, and in all places; and thus we ſhould have action without an agent: for to be abſent from all places is a phraſe of the ſame import as not to exiſt. But if a living and intelligent being cannot act but where it is either immediately or inſtrumentally preſent, much leſs ſurely can we attribute events of any kind to the agency of an abſent and inanimated body. Yet it has been ſaid, that "we have every reaſon, which the nature of the ſubject and of our own faculties can admit of, to believe, that there are among things inanimate ſuch relations, that they may be mutually cauſes or principles of change to one another, without any exertion of *power*, or any operation of an agent, ſtrictly ſo called. Such relations, for aught that we know, may take place among bodies at great diſtances from one another, as well as among bodies really or ſeemingly in actual contact; and they may vary both in degree and in kind, according to the diſtances between the bodies."

That any thing ſhould be a cauſe or principle of change to another, without the exertion of *power* or the operation of an agent, appears to us a palpable contradiction; and we could as eaſily conceive any two ſides of a triangle to be not greater than the third ſide, as reconcile ſuch a propoſition to that faculty of our minds by which we diſtinguiſh truth from falſehood. When we ſee one body the apparent cauſe of change in another body, we cannot poſſibly entertain a doubt of the *exertion of power*; but whether that power be in the body apparently producing the change, or in a diſtinct agent, is a queſtion to which an anſwer will not ſo readily be found. That it is in a diſtinct agent, we are ſtrongly inclined to believe, not only by the received doctrine concerning the inertia of matter, which, though it has been frequently controverted, we have never ſeen diſproved, but much more by conſidering the import of an obſervation frequently introduced to prove the direct contrary of our belief. "We cannot be charged (ſays the writer whom we have juſt quoted) with maintaining the abſurdity, that there may be an effect without a cauſe, when we refer the fall of a ſtone to the ground, and the ebbing and flowing of the ſea, to the *influence* of the earth on the ſtone, and of the ſun and moon on the ocean, according to the principle of general gravitation."

We admit the truth of this obſervation, provided the influence of the ſun and moon on the ocean be poſſible; but, to us at leaſt, it appears impoſſible, and is certainly inconceiveable. The *influence* of the ſun and moon can here mean nothing but the *action* or *operation* of the ſun and moon; but if theſe two bodies be inanimate, they cannot *act* at all, in the proper ſenſe of the word; and whatever they be, it is obvious that they cannot act *immediately* on an object at ſuch a diſtance from them as the earth and the ocean. If they be the agents, they muſt operate by an inſtrument, as we do when moving objects to which our hands cannot reach; but as it has been ſhewn elſewhere (ſee METAPHYSICS, n° 199. and OPTICS, n° 63. Encycl.), that neither air, nor æther, not any other material inſtrument which has yet been thought of, is ſufficient to account for the phenomena of attraction and repulſion, it is ſurely much more rational to conclude, that the ebbing and flowing of the ſea are produced, not by the influence of the ſun and moon, but by the power of ſome diſtinct agent or agents.

What thoſe agents are, we pretend not to ſay. If the Supreme Being himſelf be the immediate author of every change which takes place in the corporeal world, it is obvious that he acts by fixed rules, of which many are apparent to the moſt heedleſs obſerver, whilſt the diſcovery of others is reſerved for the reward of the judicious application of the faculties which he has given us. If he employs inferior agents to carry on the great operations of nature, it is ſurely not difficult to conceive that the powers of thoſe agents which were derived from him, may by him be reſtrained within certain limits, and their exerciſe regulated by determined laws, in ſuch a manner as to make them produce the greateſt benefit to the whole creation. Nor let it be thought an objection to this theory, that the changes which take place among bodies at great diſtances from each other, vary both in degree and in kind according to the diſtances; for this variation, which we acknowledge to be a fact, appears to us wholly unaccountable upon any other hypotheſis than that which attributes the different changes to agents diſtinct from the bodies themſelves. Did we perceive all the particles of matter, at all diſtances, tending towards each other by a fixed law, we might be led to conſider mutual attraction as an *eſſential* property of that ſubſtance, and think no more of inquiring into its cauſe, than we think of inquiring into the cauſe of extenſion. But when we find that the ſame particles, which at one diſtance ſeem to attract each other, are at a different diſtance kept aſunder by a power of repulſion, which no force, with which we are acquainted, is able to overcome, we cannot attribute the *principle* or *cauſe* of theſe changes to brute matter, but muſt refer it to ſome other agent exerting power according to a fixed law.

It is the faſhion at preſent to deſpiſe all metaphyſical inquiries as abſtruſe and uſeleſs; and on this account we doubt not but ſome of our readers will turn away from this diſquiſition with affected diſguſt, whilſt the petulant and unthinking chemiſt, proud of poſſeſſing the ſecrets of his ſcience, will deem it ſuperfluous to inquire after any other natural agents than thoſe of which he has been accuſtomed to talk. But with the utmoſt reſpect for the diſcoveries made by modern chemiſts, which we acknowledge to be both numerous and important, we beg leave to obſerve, that though theſe gentlemen have brought to light many events and operations of nature formerly unknown, and have ſhown that thoſe operations are carried on by eſtabliſhed laws, none of them can ſay with certainty that he has diſcovered a ſingle agent. The moſt enlightened of them indeed pretend not to have diſcovered in one department of ſcience more than Newton diſcovered in another; for they well know that agents and agency cannot be ſubjected to any kind of phyſical experiments. Our very notions of theſe things are derived wholly from our own conſciouſneſs and reflection; and when it is conſidered what dreadful conſequences have in another country reſulted from that pretended philoſophy which excludes the agency of mind from the univerſe, it is ſurely time to inquire whether our conſciouſneſs and reflection do not lead us to refer real agency to mind alone. Let this be our apology both to the real and to the affected enemies of metaphyſics for endeavouring to draw their attention to the preſent queſtion. It is a queſtion of the utmoſt importance, as well to ſcience as to religion, and if the laws of human thought decide it, as we have endeavoured to ſhow that they do, we may without heſitation affirm, that the impious philoſophy of France can never gain ground but among men incapable of patient thinking.

ACTON, a townſhip in Middleſex county, Maſſachuſetts, containing 853 inhabitants; 24 miles N. W. of Boſton.—*Morse.*

ACWORTH, a townſhip in Cheſhire county, New-Hampſhire, incorporated in 1766, and contains 704 inhabitants; 8 miles E. by N. from Charleſtown, and 73 N. W. by W. from Portſmouth.—*ib.*

ADAMAS, a name given, in aſtrology, to the moon.

ADAMS, a townſhip in Berkſhire county, Maſſachuſetts, containing 2040 inhabitants, is about 140 miles N. W. of Boſton. In the northern part of this town, is a great natural curioſity. A pretty mill ſtream, called Hudſon's Brook, which riſes in Vermont, and falls into the north branch of Hooſuck river, has, for 30 or 40 rods, formed a very deep channel, in ſome places 60 feet deep, through a quarry of white marble. Over this channel, where deepeſt, ſome of the rocks remain, and form a natural bridge. From the top of this bridge to the water, is 62 feet; its length is about 12 or 15, and its breadth about 10. Partly under this bridge, and about 10 or 12 feet below it, is another, which is wider, but not ſo long; for at the eaſt end they form one body of rock, 12 or 14 feet thick, and under this the water flows. The rocks here are moſtly white, and in other places clouded, like the coarſe marble common at Laneſborough, and in other towns in Berkſhire county.—*Morse.*

ADDISON *County*, in Vermont, is on the eaſt ſide of Lake Champlain, and is divided nearly into equal parts by Otter creek; has Chittenden county on the N. and Rutland county on the S. and contains 6449 inhabitants, diſperſed in 21 townſhips. It is about 30 miles by 27: a range of the green mountains paſſes through it. Chief town Middlebury, granted Nov. 1761.—*ib.*

ADSON's *Town*, lies near the N. E. line of New-Jerſey, and S. E. of the Drowned Lands; 27 miles N. of Morriſtown, and 24 N. W. of Patterſon.—*ib.*

ÆOLUS, in mechanics, a ſmall machine invented by Mr. Tidd for refreſhing or changing the air in rooms when it becomes too hot or otherwiſe unfit for reſpiration. The æolus is ſo contrived as to ſupply the place of a ſquare of glaſs in the window, where it works, with very little noiſe, like the ſails of a wind-mill or a ſmoke-jack.

AEROLOGY is a branch of ſcience which was detailed in the Encyclopædia at ſufficient length, and according to the principles which were then generally admitted by chemiſts. Subſequent experiments, however, have ſhown, that ſome of thoſe principles are erroneous, and of courſe that ſome of the opinions advanced in the article AEROLOGY are inconſiſtent with facts. Theſe opinions muſt be corrected; but inſtead of ſwelling this volume with a new article AEROLOGY, we apprehend that it will be more acceptable to our ſcientific readers to refer them for thoſe corrections to the article CHEMISTRY in this Supplement.

AFFUERA, one of the iſlands of Juan Fernandes, on the South Sea coaſt, in the kingdom of Chili. Long. from the meridian of Callao, 30. 20. about 400 leagues to the N. of Cape Horn. This coaſt ſwarms with ſea lions and wolves.—*Morse.*

AFGHANS, are a people in India who inhabit a province of CABUL or CABULISTAN (ſee Encycl.), and have always been connected with the kingdoms of Perſia and Hindoſtan. They boaſt of being deſcended of Saul the firſt king of Iſrael; of whoſe advancement to the royal dignity they give an account which deviates not very widely from the truth. They ſay indeed, that their great anceſtor was raiſed from the rank of a ſhepherd, not for any princely qualities which he poſſeſſed, but becauſe his ſtature was exactly equal to the length of a rod which the angel Gabriel had given to the prophet Samuel as the meaſure of the ſtature of him whom God had deſtined to fill the throne of Iſrael.

SAUL, whoſe deſcent, according to ſome of them, was of Judah, and according to others of Benjamin, had, they ſay, two ſons, BERKIA and IRMIA, who ſerved David, and were beloved by him. The ſons of Berkia and Irmia were AFGHAN and USBEC, who, during the reigns of David and Solomon, diſtinguiſhed themſelves, the one for his corporeal ſtrength, and the other for his learning. So great indeed was the ſtrength of *Afghan*, that we are told it ſtruck terror even into demons and genii.

This hero uſed frequently to make excurſions to the mountains; where his progeny, after his death, eſtabliſhed themſelves, lived in a ſtate of independence, built forts, and exterminated infidels. When the ſelect of creatures (the appellation which this people give to *Mahomet)* appeared upon earth, his fame reached the *Afghans*, who ſought him in multitudes under their leaders *Khalid* and *Abdul Reſpid*, ſons of *Walid;* and the prophet honouring them with this reception—"Come, O *Muluc*, or Kings!" they aſſumed the title of *Melic*, which they retain to this day.

The hiſtory, from which this abſtract is taken, gives a long and unintereſting detail of the exploits of the Afghans, and of their zeal in overthrowing the temples of idols. It boaſts of the following monarchs of their race who have ſat upon the throne of *Dehli:* Sultan BEHLOLE, *Afghan* LODI, Sultan SECANDER, Sultan IBRAHIM, SHIR SHAH, ISLAM SHAH, ADIL SHAH SUR. It alſo numbers the following kings of *Gaur* deſcended of the Afghan chiefs: SOLAIMAN *Shah Gurzani*, BEYAZID *Shah*, and KUTB *Shah;* beſides whom, their nation, we are told, has produced many conquerors of provinces. The Afghans are ſometimes called *Solaimani*, either becauſe they were formerly the ſubjects of SOLOMON king of Iſrael, or becauſe they inhabit the mountains of Solomon. They are likewiſe called PATANS, a name derived from the *Hindi* verb *Paitna* "to ruſh" which was given to them by one of the Sultans whom they ſerved, in conſequence of the alacrity with which they had attacked and conquered his enemies. The province which they occupy at preſent was formerly called *Roh;* and hence is derived the name of the *Rohillas*. The city which was eſtabliſhed in it by the *Afghans* was called by them *Paiſhwer* or *Paiſher*, and is now the name of the whole diſtrict. The ſects of the Afghans are very numerous; of which the principal are, *Lodi, Lohouni, Sur, Serwani, Yuſufzihi, Bangiſh, Dilazaui, Khetti, Yaſin, Khail*, and *Beloje*. They are *Muſulmans*, partly of the *Sunni*, and partly of the *Shiek* perſuaſion.

Though they are great boaſters, as we have ſeen, of the antiquity of their origin, and the reputation of their race, other *Muſulmans* reject their claim, and conſider them as of modern, and even of baſe extraction.

This is probably a calumny; for it ſeems inconſiſtent with their attention to the purity of their deſcent—an attention which would hardly be paid by a people not convinced of their own antiquity. They are divided into four claſſes. The firſt is the *pure* claſs, conſiſting of thoſe whoſe fathers and mothers were *Afghans*. The ſecond claſs conſiſts of thoſe whoſe fathers were *Afghans* and mothers of another nation. The third claſs contains thoſe whoſe mothers were *Afghans* and fathers of another nation. The fourth claſs is compoſed of the children of women whoſe mothers were *Afghans* and fathers and huſbands of a different nation. Perſons who do not belong to one of theſe claſſes are not called *Afghans*.

This people have at all times diſtinguiſhed themſelves by their courage, both ſingly and unitedly, as principals and auxiliaries. They have conquered for their own princes and for foreigners, and have always been conſidered as the main ſtrength of the army in which they ſerved. As they have been applauded for virtues, they have alſo been reproached for vices, having ſometimes been guilty of treachery, and of acting the baſe part even of aſſaſſins.

Such is the account of the Afghans publiſhed in the ſecond volume of the Aſiatic Reſearches. It was tranſlated from a Perſian abridgment of a book written in the Puſhto language, and called *The Secrets of the Afghans*, and communicated by Henry Vanſittart, Eſq; to Sir William Jones, then Preſident of the Aſiatic Society. Their claim to a deſcent from Saul king of Iſrael, whom they call MELIC TALUT, is probably of not a very ancient date; for the introduction of the angel Gabriel with his rod, gives to the whole ſtory the air of one of thoſe many fictions which Mahomet borrowed from the later rabbins. Sir William Jones, however, though he ſurely gave no credit to this fable, ſeems to have had no doubt but the Afghans are deſcendants of Iſrael. "We learn (ſays he) from ESDRAS, that the ten tribes, after a wandering journey, came to a country called *Arſareth*, where we may ſuppoſe they ſettled: now the *Afghans* are ſaid by the beſt *Perſian* hiſtorians to be deſcended from the *Jews*. They have traditions among themſelves of ſuch a deſcent; and it is even aſſerted, that their families are diſtinguiſhed by the names of *Jewiſh* tribes, although, ſince their converſion to *Iſlam*, they ſtudiouſly conceal their origin from all whom they admit not to their *ſecrets*. The *Puſhto* language, of which I have ſeen a dictionary, has a manifeſt reſemblance to the *Chaldaick;* and a conſiderable diſtrict under their dominion is called *Hazareh* or *Hazaret*, which might eaſily have been changed into the word uſed by ESDRAS. I ſtrongly recommend an inquiry into the literature and hiſtory of the *Afghans*."

It is to co-operate with this accompliſhed ſcholar that we have inſerted into our Work this ſhort account of that ſingular people; and it is with pleaſure that, upon the authority of Mr Vanſittart, we can add, that a very particular account of the *Afghans* has been written by the late HAFIZ RAHMAT *Khan*, a chief of the *Rohillahs*, from which ſuch of our readers as are oriental ſcholars may derive much curious information.

AGAMENTICUS, a mountain of conſiderable elevation in the diſtrict of Maine, diſtant about ſix miles from Bald Head, and eight from York harbor. Lat. 43. 16. N. and 70. 39. W. long. from Greenwich. It is a noted land-mark for ſeamen, and is a good directory for the entry of Paſcataqua harbor, as it lies very nearly in the ſame meridian with it, and with Pigeon Hill, on Cape Ann. The mountain is covered with wood and ſhrubs, and affords paſture up to its ſummit, where there is an enchanting proſpect. The cultivated parts of the country, eſpecially on the S. and S. W. appear as a beautiful garden, interſected by the majeſtic river Paſcataqua, its bays and branches. The immenſe ranges of mountains on the N. and N. W. afford a ſublime ſpectacle; and on the ſea ſide, the various indentings of the coaſt, from Cape Ann to Cape Elizabeth, are plainly in view in a clear day; and the Atlantic ſtretches to the E. as far as the power of viſion extends. At this ſpot the bearings of the following objects were taken, with a good ſurveying inſtrument, October 11, 1780.

ſides that he ſtudied nothing more, it is certain that at that time aſtronomers explained the motions of the heavens by intricate and confuſed hypotheſes, which did no honour to God, nor any wiſe anſwered the idea of an able workman. So that, from conſidering the multitude of ſpheres compoſing the ſyſtem of Ptolemy, and thoſe numerous eccentric cycles and epicycles with which it is embarraſſed, if we ſuppoſe Alphonſus to have ſaid, "that if God had aſked his advice when he made the world, he would have given him better counſel," the boldneſs and impiety of the cenſure will be greatly diminiſhed.

Such is the apology made by Dr Hutton for this royal aſtronomer of Spain; and we hope, for the honour of ſcience, that it is well founded. Still it leaves Alphonſus guilty of great irreverence of language, which is to us wholly unaccountable, if it be really true that he read the Bible fourteen times. We have ſeen impiety indeed break out lately from very eminent aſtronomers of a neighbouring nation; but theſe men read not the Bible, nor any thing elſe, but the dreams of the eternal ſleepers.

ALSTEAD, a townſhip in Cheſhire county, New-Hampſhire, containing 1111 inhabitants; 8 miles S. from Charleſtown.—*Morse.*

ALTERNATE ANGLES. See GEOMETRY (Encycl.), Part I. 35.

ALTERNATE Ratio, or *Proportion*, is the ratio of the one antecedent to the other, or of one conſequent to the other, in any proportion, in which the quantities are of the ſame kind. So if A : B :: C : D, then alternately, or by alternation A : C :: B : D.

ALTITUDE, PARALLAX OF, is an arch of a vertical circle, by which the true altitude, obſerved at the centre of the earth, exceeds that which is obſerved on the ſurface. See PARALLAX (Encycl.) and ASTRONOMY (*Suppl.*)

ALTITUDE of the Nonageſimal, is the altitude of the 90th degree of the ecliptic, counted upon it from where it cuts the horizon, or of the middle or higheſt point of it which is above the horizon, at any time; and is equal to the angle made by the ecliptic and horizon where they interſect at that time.

ALTITUDE of the Cone of the Earth's or Moon's Shadow, the height of the ſhadow of the body made by the ſun, and meaſured from the centre of the body. To find it ſay, As the tangent of the angle of the ſun's apparent ſemidiameter is to radius; ſo is 1 to a fourth proportional, which will be the height of the ſhadow in ſemidiameters of the body.

ALUM is a ſalt ſo uſeful in commerce and the arts, that the knowledge of its component parts, and of the beſt method of preparing it, muſt be of importance. In the article CHEMISTRY (Encycl.), the opinions which were then held reſpecting its compoſition, and the practice which was generally followed in its preparation, have been detailed at full length; but ſome of theſe opinions have ſince been controverted, and if they be erroneous, it muſt be expedient to vary in ſome degree the mode of preparation. In particular, the opinion that it is merely an exceſs of acid which prevents the formation of alum by evaporation of the ley, has been ſhown to be falſe by Citizen *Vauquelin*, who contends, of courſe, that the addition of putrid urine to the ley is a very bad practice.

This eminent chemiſt had long ſuſpected, that the cryſtallization of alum is not prevented by an exceſs of acid, and that pot-aſh is not of uſe ſimply to ſaturate this acid, but to perform an office of more importance. To bring his ſuſpicions to the teſt of experiment, he diſſolved very pure ALUMINE in ſulphuric acid of equal purity, and evaporated the ſolution to dryneſs, for the purpoſe of expelling the ſuperabundant acid. He then rediſſolved the dry and pulverulent reſidue in water, and reduced the ſolution to different degrees of ſpecific gravity, with a view to ſeize the point moſt favourable to cryſtallization; but with every poſſible precaution he could obtain nothing but a magma (ſee MAGMA), formed of ſaline plates, without conſiſtence or ſolidity. This ſolution, however, though it conſtantly refuſed to afford cryſtallized alum alone, afforded it immediately by the addition of a few drops of the ſolution of pot-aſh; and as he had employed theſe two ſubſtances in the requiſite proportion, the reſt of the ſolution, to the very end, afforded pure alum, without any mixture of ſulphate of pot-aſh.

Into another portion of the ſame ſolution of pure alumine he dropped the ſame quantity of carbonate of ſoda, as he had added of that of pot-aſh to the former; but no cryſtallization was formed, even by the help of evaporation, nor did lime and barytes produce any better effect. But if the common opinion that pot-aſh, in the formation of alum, is of uſe only to abſtract the exceſs of acid, be true, ſoda, lime, barytes, and all the ſubſtances which by a more powerful force would take this acid from alum, ought to give the ſame reſult. Another argument preſented itſelf, which ſeemed deciſive: If the alkalis, pot-aſh, and ammoniac, do nothing more than unite to the ſuperabundant acid of the alum, the ſulphates of pot-aſh and of ammoniac ought not to occaſion any change in pure alum in its acidulated ſtate; whereas if theſe alkalis enter as a conſtituent part into the alum, and are neceſſary to its exiſtence, they ought to produce the ſame effects as pure pot-aſh or ammoniac. He therefore added to a third portion of the ſolution of ſulphate of alumine before-mentioned ſome drops of the ſolution of ſulphate of pot-aſh; immediately upon which octahedral cryſtals of alum were formed. The ſulphate of ammoniac preſented the ſame effect.

This reſult gave ſtill greater confirmation to his firſt notions, though it did not yet afford a demonſtration perfectly without objection; for it might have happened that the two ſalts he made uſe of might determine the cryſtallization of the alum, ſimply by abſorbing the ſuperfluous acid, of which they are very greedy; but to determine this poſſible fact, he mixed in the uncryſtallizable ſolution of alumine ſome ſulphate of pot-aſh with exceſs of acid, and obtained a cryſtallization no leſs abundant than with the neutral ſulphate of pot-aſh.

This laſt experiment leaves therefore no doubt with regard to the influence and mode of action of pot-aſh and ammoniac in the fabrication of alum; and this action is ſtill more ſtrongly confirmed by the examination of the alums which have been formed by the proceſſes above related; for in this manner it is proved that they contain conſiderable quantities of the ſulphates of pot-aſh and ammoniac.

Theſe experiments led M. Vauquelin to an examination of the different alums of commerce, of which he found not one that did not afford ſulphate of pot-aſh, Alum.

or of ammoniac, or of both. His methods of analyſis are very accurate; but to detail them at length would ſwell this article to little purpoſe. To ſuch of our readers as are not chemiſts they would hardly be intelligible; and the experienced chemiſt will deviſe methods of analyſis for himſelf. It may be proper, however, to obſerve, that M. Vauquelin proved, to his own ſatisfaction, that the ſulphate of pot-aſh, or of ammoniac, is neceſſary to render alum capable of being precipitated by its earth, or to cauſe it to paſs, as it were, to the earthy ſtate (A). He proved likewiſe, that ſuch aluminous waters as do not contain pot-aſh, may remain, as long as may be deſired, on their materials, without being ſaturated with too great a quantity of earth, or ſuffering alum to precipitate.

From the whole of his experiments our author drew the following concluſions, which he conſiders as of importance to the arts, to chemiſtry, and to natural hiſtory.

1. It is not, at leaſt in the greateſt number of circumſtances, the exceſs of acid which impedes the cryſtallization of alum, but it is the want of pot-aſh or ammoniac: For it is difficult to imagine that the ſulphuric acid could remain diſengaged after ſo long remaining upon alumine in a ſtate of extreme diviſion, and always ſuperabundant. It is true that the aluminous waters redden the vegetable tinctures; but this property is not owing to a diſengaged acid. This portion of acid is a conſtituent part of theſe waters; and it appears to have more affinity with the neutral ſulphate of alumine than with a new quantity of this earth at the temperature of the atmoſphere.

2. The ſulphate of pot-aſh may be uſed, as well as pure pot-aſh, to cauſe the cryſtallization of alum. It even has the advantage over the latter ſalt, becauſe if the aluminous waters do not really contain a diſengaged acid, the pot-aſh, in its combination, will precipitate a portion of alumine, and diminiſh the product of the boiling; whereas the ſulphate of pot-aſh does not produce the ſame effect; but if the lixiviums contain diſengaged acid, which muſt very ſeldom be the caſe, it is not converted into alum by the ſulphate of pot-aſh, and is loſt with regard to the product. Our author therefore is of opinion, that when the waters really contain an exceſs of acid, or a very oxided ſulphate of iron, the uſe of pot-aſh is preferable to that of the ſulphate of pot-aſh. But when economy is an object, that in many places it would be profitable to uſe the ſulphate of pot-aſh; becauſe it is a ſalt indirectly produced in many manufactories, where of courſe it may be obtained for nothing. In particular, the reſidues of the diſtillation of aquafortis by the ſulphuric acid would be excellent for this operation, and much preferable to putrid urine, becauſe this fluid always contains phoſphoric ſalts, which decompoſe a portion of the ſulphate of alumine, and conſiderably diminiſh the product.

3. Alumine cannot be uſed in the treatment of mother waters, as Bergman propoſes. This earth is incapable of favouring the cryſtallization of alum, beſides which, it decompoſes a portion of alum by the aſſiſtance of ebullition; in which circumſtance it ſeizes the acid neceſſary to its ſolution, and precipitates it in the form of that powder which is called alum ſaturated with its earth.

4. Many alum ores muſt naturally contain pot-aſh, becauſe perfect alum is often obtained from the firſt cryſtallization of new alum waters without the addition of this alkali. It is true that an objection may be made with regard to the wood uſed in calcining theſe ores, which may be ſuppoſed to have furniſhed the alkali; but it is not probable that the ſmall quantity of wood employed, in compariſon to the quantity of ore and the alum it affords, could ſupply enough of pot-aſh for the cryſtallization.

5. All the earths and ſtones which have given, or ſhall hereafter afford, by analyſis with the ſulphuric acid, perfect alum without addition of pot-aſh, muſt contain this alkali naturally. For it is well proved, that alum cannot exiſt without pot-aſh or ammoniac; and as there is little probability that this laſt ſhould be found combined in earths or ſtones, unleſs perhaps in very rare caſes, we may almoſt conſtantly be aſſured, when alum is obtained from any of theſe ſubſtances, that its formation was effected by pot-aſh. The quantity of alum will immediately ſhow in what proportion this alkali exiſted in the ſubſtances analyſed.

6. The alum of commerce ought not to be conſidered as a ſimple ſalt, but as a combination in the ſtate of a tripple and ſometimes quadruple ſalt of ſulphate of alumine, ſulphate of pot-aſh, or of ammoniac. Among theſe laſt we may diſtinguiſh two ſpecies; the one without exceſs of acid, inſoluble in water and inſipid, being what is improperly called alum ſaturated with its own earth; and the other, which contains an exceſs of acid ſoluble in water, very ſapid and aſtringent, is the common alum.

There is likewiſe a pure ſulphate of alumine, very aſtringent, very difficult of cryſtallization, in the form of brilliant pearl-coloured plates without conſiſtence, and which cannot be rendered ſoluble by the addition of a new quantity of its baſe. This laſt ſalt may with the greateſt propriety be called the ſulphate of alumine.

7. It follows from the comparative analyſis, and the knowledge acquired reſpecting the different ſtates of the combination of alumine with the ſulphuric acid united at the ſame time with other baſes, that we muſt diſtinguiſh ſeven ſtates in this combination, and that it is neceſſary to expreſs them according to the rules of the methodical nomenclature. Here follow the ſeries, the nature, and the names of theſe ſeven ſulphates of alumine.

1. Sulphate of alumine, or the artificial combination of ſulphuric acid and alumine. This ſalt is aſtringent; it cryſtallizes in laminæ or flexible leaves, ſoluble in water. It has never been deſcribed nor named by chemiſts. 2. Acid ſulphate of alumine is the foregoing ſalt, with exceſs of acid, from which it differs by reddening blue vegetable colours. It is eaſily made by diſſolving that ſalt in the ſulphuric acid, but it is not eaſy to convert this into the neutral ſulphate of alumine but by boiling it a long time with its earth. This ſalt, like the firſt, has not been deſcribed. 3. Saturated

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(A) It may be proper to notice, that Scheele ſeems to have known this long before, and that he mentions it expreſsly in his paper on *Pyrophorus*.

ſulphate of alumine and of pot-aſh is the alum of the chemiſts ſaturated with its earth. It is pulverulent, inſipid, inſoluble, not cryſtallizable, and is eaſily converted into true alum by the addition of ſulphuric acid. 4. The acid ſulphate of alumine and of pot-aſh greatly reſembles common alum, and is eaſily prepared chemically; but M. Vauquelin found no alum but that of La Tolfa which is exactly of the ſame nature with it. 5. The acid ſulphate of alumine and of ammoniac has all the properties of alum, and may be uſed for the ſame purpoſes; but though it is eaſily made in the laboratories, our author never found it pure in commerce. 6. The acid ſulphate of alumine, pot-aſh, and ammoniac. It is remarkable enough, ſays M. Vauquelin, that this ſhould be the nature of the alum moſt frequently made in the arts, and that to expreſs its combination ſo many words ſhould be neceſſary. This, however, may be avoided, by reſerving the name of alum to this ſubſtance, which will be ſufficient to diſtinguiſh it perfectly. 7. The acidulous ſulphate of alumine and of pot-aſh, our author ſays, he is leſs acquainted with than with the preceding ſeries. The name by which he characterizes it was ſuggeſted to him, and he thinks it proper, becauſe by adding to the ſolution a ſmall quantity of pot-aſh more than is neceſſary to obtain octahedral cryſtals, it manifeſtly paſſes to the cubic form.

From theſe deductions, the phyſician, the chemiſt, and the manufacturer, with whom the uſes of alum are greatly multiplied, will hereafter poſſeſs a knowledge of the ſubſtance they employ, and may appreciate its effects on the animal economy, and other bodies to which it is ſo frequently applied. See *Annales de Chimie*, xxii. 258, and *Nicholſon's Journal*, Vol. I. p. 318, &c.

ALUMINE, one of the ſimple earths. See CHEMISTRY in this *Supplement*.

ALVARADO, a river in New Spain, which riſes in the mountains of the Zapotecas, and, after making a circuit through the province of Mazaltan, and receiving ſeveral ſmaller rivers and ſtreams, empties into the Gulf of Mexico, at 30 miles diſtance from Vera-Cruz.—*Morſe.*

AMBROSE, ST. an iſland in the S. Pacific ocean, on the coaſt of Chili, 4 or 5 leagues due W. from St. Felix iſland. At firſt view, it appears like two ſmall iſlands, but after a nearer approach, it is found they are joined by a reef. It lies in 26. 13. S. lat. and 80. 55. W. long. from Greenwich. There is a large rock 4 miles to the northward of the iſland, called, from its appearance, *Sail rock.* Capt. Roberts, who was here in 1792, found St. Felix iſland inacceſſible. On St. Ambroſe iſland, his crew killed and cured 13,000 ſeal ſkins of the beſt quality, in ſeven weeks. The iſland has little elſe to recommend it. Fiſh and crawfiſh abound. The beſt ſeaſon for ſealing is from the 1ſt of April to the 1ſt of Auguſt. The iſland has the appearance of having had volcanic eruptions.—*ib.*

AMELIA, a county in Virginia, bounded N. by Appamatox river which ſeparates it from Powhatan and Cheſterfield counties, N. W. by Prince Edward, E. by Dinwiddie, and S. by Nottaway. *Scott.* Amelia, including Nottaway, a new county, contains 18,097 inhabitants, of whom 11,037 are ſlaves.

AMELIA *Iſle*, on the coaſt of E. Florida, lies about 7 leagues N. of St. Auguſtine, and very near Talbot iſland on the S. at the mouth of St. John's river. It is 13 miles long and 2 broad, is very fertile, and has an excellent harbour. Its N. end lies oppoſite Cumberland iſland, between which and Amelia Iſle is the entry into St. Mary's river, in N. lat. 30. 52. W. long. 67. 23.—*Morſe.*

AMICABLE NUMBERS have been defined, and the firſt pair of them given in the Encyclopædia. The ſecond pair of amicable numbers are 17296 and 18416; and the third pair are 9363584 and 9437056.

Dr. Hutton informs us, that theſe three pairs of amicable numbers, with the properties from which they receive their name, were found out by F. Schooten, as appears from Sect. ix. of his *Exercitationes Mathematicæ.* To find the firſt pair, he puts $4x$ and $4yz$, or a^2x and a^2yz for the two numbers where $a=2$; then making each of theſe equal to the ſum of the aliquot parts of the other, gives two equations, from which are found the values of x and z, and conſequently aſſuming a proper value for y, the two amicable numbers themſelves $4x$ and $4yz$.

In like manner for the other pairs of ſuch numbers; in which he finds it neceſſary to aſſume $16x$ and $16yz$, or a^4x and a^4yz for the ſecond pair, and $128x$ and $128yz$ or a^7x and a^7yz for the third pair.

Schooten then gives this practical rule, from Deſcartes, for finding amicable numbers, viz. aſſume the number 2, or ſome power of the number 2, ſuch that if unity or 1 be ſubtracted from each of theſe three following quantities, viz. from 3 times the aſſumed number, alſo from 6 times the aſſumed number, and from 18 times the ſquare of the aſſumed number, the three remainders may be all prime numbers; then the laſt prime number being multiplied by double the aſſumed number, the product will be one of the amicable numbers ſought, and the ſum of its aliquot parts will be the other. That is, if a be put = the number 2, and n ſome integer number, ſuch that $3a^n-1$, and $6a^n-1$, and $18a^{2n}-1$ be all three prime numbers; then is $\overline{18a^{2n}-1}\times 2a^n$ one of the amicable numbers; and the ſum of its aliquot parts is the other.

AMSTERDAM and ST PAUL, are two iſlands in the South Sea, lying in the ſame degree of longitude, and generally confounded with each other. The Dutch navigators have given the name of *Amſterdam* to the northern, and of *St Paul* to the ſouthern iſland, and Captain Cook conforms to that appellation. Moſt other Engliſh navigators, and particularly Meſſrs Cox and Mortimer, with Sir George Staunton, reverſe the names, calling the ſouthern iſland Amſterdam, and the other St Paul. At this ſouthern iſland the Lion man of war ſtopped on her voyage to China with Lord Macartney, the late ambaſſador to the court of Pekin, which gave an opportunity to the men of ſcience in the train of the ambaſſador to examine the iſland with more ſkill and attention than probably it had ever been examined before.

Dr Gillan, who was appointed phyſician to the embaſſy, as well for his knowledge of chemiſtry as for his medical ſkill, is confident that the iſland of Amſterdam is the product of ſubterraneous fire, as it bears in every part of it evident marks of volcanic eruption. "On the weſt and ſouth-weſt ſides (ſays he) there are four ſmall cones regularly formed, with craters in their centres, in which the lava and other volcanic ſubſtances have every appearance of recent formation. The heat continues ſtill ſo great, and ſuch a quantity of elaſtic vapour iſſues through numberleſs crevices, that there can be no doubt of their having been very lately in a ſtate of eruption. In a thermometer placed upon the ſurface, the quickſilver roſe conſtantly to 180 degrees, and when ſunk a little into the aſhes, it advanced to 212 degrees. It certainly would have riſen ſtill higher; but the ſcale being graduated only to the point of boiling water, and the length of the tube proportioned to that extent, the thermometer was immediately withdrawn, leſt the increaſing expanſion of the quickſilver ſhould burſt the glaſs. The ground was felt tremulous under the feet; a ſtone thrown violently upon it returned a hollow ſound; and the heat was ſo intenſe for a conſiderable diſtance around, that the foot could not be kept for a quarter of a minute in the ſame poſition without being ſcorched. But the great crater on the eaſtern ſide, now full of water, is by far the largeſt here, or perhaps elſewhere, and is of an aſtoniſhing ſize, conſiderably exceeding in diameter thoſe of Etna or Veſuvius. The quantity of matter to be thrown up, which required ſo wide an orifice for its paſſage, and the force with which ſuch matter was impelled, in order to overcome the reſiſtance of the ſuperincumbent earth and ſea, muſt have been indeed prodigious.

“ This vaſt crater, according to the uſual method of computing the antiquity of volcanoes, muſt have been formed at a very remote period. The lava all around its ſides is much decompoſed, and has mouldered into duſt, which lies on the ſurface in many parts to a conſiderable depth. The decompoſition has ſupplied a rich ſoil for the long graſs growing on the ſides of the crater, and has even ſpread over moſt parts of the iſland. The fibrous roots of the graſs, extending in all directions through the decompoſed lava and volcanic aſhes, and mixed in a decaying ſtate with the vegetable mould, produced from the annual putrefaction of the leaves and ſtalks, have formed a layer of ſoil ſeveral feet deep all over the iſland. But as it has nothing except its own weight to compreſs it together, it is of a light ſpongy texture, with very little coheſion, and in many places furrowed and interſected by the ſummer rains, and the torrents occaſioned by the melting of the ſnow which lies upon it in the winter, from three to four feet thick, in all thoſe places where the ſubterraneous heat is not great enough to prevent its accumulation. In ſome parts theſe furrows and cavities are deeper than the level of the common channel; hence they ſerve the purpoſe of ſmall natural reſervoirs. The water flows into them from all the neighbouring ground; and as their ſides are ſhaded, and almoſt covered over by the leaves of the long graſs, growing from their edges in oppoſite directions, the rays of the ſun are excluded, and very little is loſt by evaporation. Theſe reſervoirs, however, are very ſmall, and but few in number; the largeſt could not contain more than three or four hogſheads of water; and there is none elſe to be found, except in the ſprings on the ſides of the large crater.

“ The ſoil everywhere being light and ſpongy, and full of holes, formed in it by ſea-birds for neſts, is very troubleſome to walk upon; the foot breaks through the ſurface, and ſinks deep at every ſtep; a circumſtance which renders the journey acroſs the iſland uncommonly fatiguing, although it be ſcarcely three miles from the edge of the great crater to the oppoſite weſt ſide. There is one place near the centre of the iſland, extending about 200 yards in length, and ſomewhat leſs in breadth, where particular caution is neceſſary in walking over it. From this ſpot a hot freſh ſpring is ſuppoſed to derive its ſource, finding its way through the interſtices of the lava to the great crater, and burſting out a little above the water covering its bottom. The heat in this upper ſpot is too great to admit of vegetation. The ſurface is covered with a kind of mud or paſte formed from the aſhes, moiſtened by ſteam conſtantly riſing from below. When the mud is removed, the vapour iſſues forth with violence, and in ſome parts copiouſly. This mud is ſo hot, that a gentleman who inadvertently ſtepped into it, had his foot ſeverely ſcalded by it. The ſame cauſes which have prevented vegetation on this ſpot, have had the ſame effect on the four cones recently thrown up. Their ſurfaces are covered with aſhes only; nor is there the leaſt appearance even of moſs on the ſurrounding lava, for the production of which there does not appear to have elapſed a ſufficient length of time ſince the cones were formed: but this is not the caſe with the lava of the great primary crater; for in thoſe parts of it where the edges are more perpendicular, and where conſequently the mouldering decompoſed earth, having no baſis to ſupport it, ſlides down the ſides of the rock, pretty long moſs was generally found growing upon it. All the ſprings or reſervoirs of hot water, except one only, were brackiſh. One ſpring derives its ſource from the high ground and ridges of the crater. The water in it, inſtead of boiling upwards through the ſtones and mud, as in the other ſprings, flows downward with a conſiderable velocity, in a ſmall collected ſtream. Its temperature has been found not to exceed 112 degrees. The hand could be eaſily kept in it for a conſiderable time. It is a pretty ſtrong chalybeate. The ſides of the rock whence it iſſues, and of the cavity into which it falls, are incruſted with ochre depoſited from it.

“ When the great crater is viewed from the high ground, it appears to have been originally a perfect circle, but to have been encroached upon by the ſea on the eaſtern ſide, where the flood tide ſtrikes violently. The rocks of lava which formed the edge of the crater on that ſide have fallen down. The depth of the water in the crater is about 170 feet, rendering the whole height of the crater, from the bottom to its upper ridge, nearly if not quite 900 feet. The lofty rocks forming this ridge are the higheſt parts of the iſland, which ſeems to have been originally produced by the melted lava flowing down on all ſides from hence. Thus there is a gradual ſlope from the edges of the crater to the ſea; and the lava, though very irregular, and lying in mixed ruin and confuſion immediately around the crater, aſſumes a more uniform appearance at ſome diſtance, layer reſting regularly upon layer, with a gradual declivity the whole way down to the ſea. This diſpoſition of the layers is particularly obſervable in the weſt ſide, where they happen to terminate in an abrupt precipice. The eruptions that took place at different periods appear here diſtinctly marked by the different layers that are found with regular diviſions between them; the glaſſy lava being undermoſt, the compact next, the cellular lava next above, over it the volcanic aſhes and lighter it picks up as they are ſwimming over the ſurface of the water.

This ſingular iſland lies in 38° 42′ S. Lat. and in 76° 54′ E. Long. from Greenwich. St Paul's, or the iſland lying in ſight and to the northward, differed in appearance materially from Amſterdam. It preſented no very high land, or any riſing in a conic form; and ſeemed to be overſpread with ſhrubs or trees of a middling ſize. It was ſaid to abound with freſh water, but to have no good anchorage near it, nor any place of eaſy landing.—*Sir George Staunton's Account of an Embaſſy to the Emperor of China.*

AMELINS, *Ecor a*, is a ſouth eaſtern head branch of Wabaſh river, whoſe mouth is 9 miles N. E. from the mouth of Salamanie river, and 45 miles S. W. from the Miami village and fort.—*Morſe.*

AMOENIA, a thriving townſhip in Dutcheſs county, New-York, 6 miles diſtant from Sharon, in Connecticut. It contains 3078 inhabitants, of whom 383 are electors.—*ib.*

AMHERST, a townſhip in Cumberland county, Nova-Scotia, ſituated on Chignecto Baſon, on the S. ſide of La Planch River, and on the rivers Napan and Macon. The navigation of the two laſt is difficult on account of ſhoals. The town was ſettled by North Iriſh, Yorkſhire and New-England people.—*ib.*

Amherst, the ſhire-town of Hillſborough county, New-Hampſhire, is a town of ſome note, formerly *Souhegan Weſt*, and was originally granted from *Maſſachuſetts*. It has 2369 inhabitants, and was incorporated in 1762. The Aurean Academy was founded here in 1790. A few years ago, the townſhip being much infeſted with wolves, the people, on a day appointed, ſurrounded a large ſwamp which they frequented, and kept up an inceſſant firing of guns and beating of drums the whole day; which muſic forced the wolves to decamp the following night, with diſmal howlings; and they have never done any miſchief in the town ſince. Amherſt lies on a northern branch of Souhegan River, which falls into Merrimack River, and is 60 miles W. of Portſmouth, and 53 N. W. of Boſton. N. lat. 42. 54. W. long. 71. 33.—*ib.*

Amherst, a townſhip in Hampſhire county, Maſſachuſetts, containing 1233 inhabitants; 91 miles weſterly from Boſton, and about eight north-eaſterly from Northampton.—*ib.*

Amherst *County*, in Virginia, lies between the Blue Ridge and the tide waters, and contains 13,703 inhabitants, including 5296 ſlaves. It lies on the north of James River.—*ib.*

AMICU, a lake in the province of Cumana, South-America, whoſe waters run ſouthwardly through Parima River into the Amazon.—*ib.*

AMONOOSUCK, an Indian name given to two rivers in New-Hampſhire: the one is called *Upper* Amonooſuck, paſſing through a tract of excellent meadow. It riſes near the north end of the White Hills, runs northerly about 15 miles, where is a carrying place of about three miles to Amariſcoggin River. From thence the river runs S. W. and W. nearly 18 miles, and empties into the Connecticut at Northumberland, near the Upper Coos.

The other is called *Great* or *Lower* Amonooſuck, which riſes on the weſt ſide of the White Mountains. It falls into the Connecticut juſt above the town of Haverhill, in Lower Coos, by a mouth 100 yards wide. About two miles from its mouth it receives *Wild Amonooſuck*, 40 yards wide from Franconia and Lincoln Mountains. Two or three hours rain raiſes the water in this laſt mentioned river ſeveral feet, and occaſions a current ſo furious as to put in motion ſtones of a foot in diameter, but its violence ſoon ſubſides. —*ib.*

AMOTAPE, a town near Tumbez, lying near the ſhore of the South Sea, in the empire of Peru. Being near a river of fine water, the adjacent country is highly improved. Lat. 4. 15. 43. S.—*ib.*

AMPALLA, by ſome authors called *Ampalia*, a city and ſeaport in Guatimala Gulf, in that of Mexico, 350 miles S. E. of the city of Guatimala, and carries on a briſk trade in cochineal, cocoa, hides, indigo, &c.—*ib.*

AMPARES, a juriſdiction under the archbiſhop of Plata, eaſtward of that city, in the empire of Peru. It abounds in grain and cattle.—*ib.*

AMUSKEAG *Falls*, in New-Hampſhire, are on Merrimack River, ſixteen miles below Concord, and ſeven below Hookſet Falls. It conſiſts of three pitches, one below the other, ſo that the water falls about 80 feet in the courſe of half a mile. The ſecond pitch, which may be ſeen from the road, on the W. ſide, is truly majeſtic. In the middle of the upper part of the fall is a high rocky iſland, on the top of which are a number of pits, made exactly round, like barrels or hogſheads, ſome of which are capable of holding ſeveral tons; formed by the circular motion of ſmall ſtones, impelled by the force of the deſcending water. There is a bridge acroſs the falls 556 feet in length, and 20 in breadth, conſiſting of 2000 tons of timber, and made paſſable for travellers 57 days after it was begun. N. lat. 42. 59.—*ib.*

ANACLASTIC curves, a name given by M. de Mairan to certain apparent curves formed at the bottom of a veſſel full of water, to an eye placed in the air; or the vault of the heavens, ſeen by refraction through the atmoſphere.

ANAPHORA, in aſtrology, the ſecond houſe, or that part of the heavens which is 30 degrees from the horoſcope. The term *anaphora* is alſo ſometimes applied promiſcuouſly to ſome of the ſucceeding houſes, as the 5th, the 8th, and the 11th. In this ſenſe *anaphora* is the ſame as *epanaphora*, and ſtands oppoſed to *cataphora*.

ANASTATIA, St. a ſmall iſland cloſe to the coaſt of Eaſt-Florida, ſituated S. of Maſtances Inlet, where the river Maſtances forms two iſlands of the ſame name at its mouth. St. Anaſtatia iſland is bounded on the N. by St. Auguſtine's bar. Here is a quarry of fine ſtone for building.

ANASTROUS signs, in aſtronomy, a name given to the *duodecatemoria*, or the twelve portions of the ecliptic, which the ſigns poſſeſſed anciently, but have ſince deſerted by the preceſſion of the equinox.

ANCHOR of a ship, is an inſtrument which, as it is commonly made, has been ſufficiently deſcribed in the Encyclopædia. An improvement, however, has been propoſed on its conſtruction by Mr James Stuard of the pariſh of St Anne, Middleſex, who obtained a patent for his invention, dated Feb. 9, 1796.

The whole of this invention conſiſts in making the anchor with one fluke or arm inſtead of two, and contriving to load that fluke or arm in ſuch a manner as to make it always fall the right way. With this view Mr Stuard would have the ſhank of the anchor made very ſhort, that it may *cant* the more when ſuſpended by the cable; and he would have the arm and it made of bars in one length, that there may be no ſhoot or joining in the whole inſtrument. The bend of the ſhank and arm he would have rounded, and not angular as in the common anchor; and on this bend he would have a ſmall ſhackle, or two plates with a ſmall bolt between them, for the buoy-rope to be made faſt to. Inſtead of wood. he propoſes for the ſtock of the anchor a bar of wrought iron, loaded or covered at the ends with knobs of caſt iron; and he would have the palm of the fluke or arm either to be compoſed entirely of caſt iron, or to be a caſt iron ſhell filled with lead. This weight of the palm, the ſhortneſs of the ſhank, and the ſtructure of the ſtock, will no doubt make the anchor fall the right way; which, having no upper fluke, will never be tripped by the cable taking hold of it on the ſhip's ſwinging, nor will it prove ſo dangerous as the common anchor to ſuch veſſels as may happen to ground by it.

ANCOCUS or RANCOCUS *Creek*, in New-Jerſey, a water of the Delaware, 6 miles S. W. from Burlington. It is navigable 16 miles; and conſiderable quantities of lumber are exported from it—*Morse.*

ANDAGUAYLAS, a juriſdiction in South-America, in the empire of Peru, ſubject to the archbiſhop of Lima; lying E. by S. of the city of Guamanga. It abounds in ſugar plantations, grain of moſt ſorts, and fruits.—*ib.*

ANDERSON (Alexander), an eminent mathematician, was born at Aberdeen towards the end of the 16th century. Where he was educated, or under what maſters, we have not learned; probably he ſtudied the belles lettres and philoſophy in the univerſity of his native city, and, as was the practice in that age of all who could afford it, went afterwards abroad for the cultivation of other branches of ſcience. But wherever he may have ſtudied, his progreſs in ſcience muſt have been rapid; for, early in the 17th century, we find him profeſſor of mathematics in the univerſity of Paris, where he publiſhed ſeveral ingenious works; and among others, 1. *Supplementum Apollonii Redivivi; ſive analyſis problematis hactenus deſiderati ad Appollonii Pergæi doctrinam* ϖερι νευσεων, *a Marino Ghetaldo Patritio Raguſino hujuſque, non ita pridem reſtitutam. In qua exhibetur mechanice æqualitatum tertii gradus ſive ſolidarum, in quibus magnitudo omnino data, æquatur homogeneæ ſub altero tantum coefficiente ignoto. Huic ſubnexa eſt variorum problematum practice*, Paris, 1612, *in* 4to.—2. Λιτιολογια: *Pro Zetetico Apolloniani problematis a ſe jam pridem edito in ſupplemento Apollonii Redivivi. Ad clariſſimum et ornatiſſimum virum Marinum Ghetaldum Patritium Raguſinum. In qua ad ea quæ obiter mihi perſtrinxit Ghetaldus reſpondetur, et analytices clarius detegitur.* Paris, 1615, in 4to.—3. *Franciſci Vietæ Fontenacenſis de Æquationum Recognitione et Emendatione Tractatus duo,* with a dedication, preſace, and appendix, by himſelf. Paris, 1615, in 4to.—4. Vieta's *Angulares Sectiones;* to which he added demonſtrations of his own. Our profeſſor was couſin german to Mr David Anderſon of Finſhaugh, a gentleman who alſo poſſeſſed a ſingular turn for mathematical knowledge. This mathematical genius was hereditary in the family of the Anderſons; and from them it ſeems to have been tranſmitted to their deſcendants of the name of Gregory, who have for ſo many generations been eminent in Scotland as profeſſors either of mathematics, or, more lately, of the theory and practice of phyſic. The daughter of the David Anderſon juſt mentioned, was the mother of the celebrated James Gregory, inventor of the reflecting teleſcope; and obſerving in her ſon, while yet a child, a ſtrong propenſity to mathematical ſtudies, ſhe inſtructed him in the elements of that ſcience herſelf. From the ſame lady deſcended the late Dr Reid of Glaſgow, who was not leſs eminent for his knowledge of mathematics than for his writings as a metaphyſician.

The preciſe dates of Alexander Anderſon's birth and death, we have not learned either from Dempſter, Mackenzie, or Dr Hutton, who ſeems to have uſed every endeavour to procure information; nor are ſuch of his relations as we have had an opportunity of conſulting, ſo well acquainted with his private hiſtory as we expected to find them.

ANDOVER, a large, fertile and thriving town in Eſſex county, Maſſachuſetts. It contains 2863 inhabitants, in two pariſhes. In the South pariſh are a paper mill and powder mill, from the latter of which the army received large ſupplies of gun-powder in the late war. There is an excellent academy in this town, called "Phillips Academy," which owes its exiſtence to the liberal benefactions of the family whoſe name it bears. Andover is under excellent cultivation, particularly that part which is watered by Shawſheen River. It lies about 20 miles W. from Newburyport, and about 22 N. from Boſton.—*Morse.*

Andover, in Hillſborough, New-Hampſhire, contains 645 inhabitants, and was incorporated in 1779.—*ib.*

Andover, is the ſouth-weſternmoſt townſhip in Windſor county, Vermont, has Cheſter on the E. lies 32 miles N. E. of Bennington, and contains 275 inhabitants.—*ib.*

Andover, a place in Suſſex county, New-Jerſey, near the ſource of Pequeſt river, 5 miles S. E. from New-Town, and 16 in the ſame direction from Walpack.—*ib.*

ANDREW's, St. a ſmall town in the conteſted country between New-Brunſwick and the United States; ſituated in the rear of an iſland of the ſame name, on the E. ſide of the arm of the inner bay of Paſſamaquoddy, called Scoodick. The town is regularly laid out in the form of an oblong ſquare. The few inhabitants are chiefly employed in the lumber trade. The common tide riſes here about 18 feet.—*ib.*

Andrew's, St. a townſhip in Caledonia county, Vermont, 100 miles N. E. from Bennington.—*ib.*

Andrew's, St. a pariſh in Charleſton diſtrict, South-Carolina, containing 2947 inhabitants, of whom 370 are whites and 2546 ſlaves.—*ib.*

Andrew's Sound, St. lies S. of Jekyl's Iſland, and is formed by it and a ſmall iſland at the mouth of Great Satilla river. The ſmall river oppoſite this ſound ſeparates Camden from Glynn county, in Georgia.—*ib.*

ANDROSCOGGIN, or *Amariſcoggin river*, in the diſtrict of Maine, may be called the main weſtern branch of the Kennebeck. Its ſources are N. of Lake Umbagog.

Cape was ſo named in honour of Ann, conſort of King James I.—*ib.*

ANN, ST. a lake in Upper Canada, northerly from Lake Superior, which ſends its waters north-eaſterly into James's Bay, through Albany River. Its north-eaſtern point lies in N. lat. 50. W. long. 88.—*ib.*

ANN, ST. is the chief town of the province of Parana, in the E. diviſion of Paraguay, South-America.—*ib.*

ANN's, ST. a port on the E. ſide of Cape Breton Iſland, where fiſhing veſſels often put in. It lies on the N. W. ſide of the entrance into Labrador Lake. W. long. 60. N. lat. 47.—*ib.*

ANN's, ST. is a ſmall town on the River St. John's, province of New-Brunſwick, about 80 miles from St. John's. It is at preſent the ſeat of government.—*ib.*

ANN, FORT, in the ſtate of New-York, lies at the head of batteaux navigation, on Wood Creek, which falls into South Bay, Lake Champlain, near Skeneſborough. It lies 6¼ miles S. W. by S. from Skeneſborough Fort; 10 E. S. E. from Fort George, and 12 N. E. by N. from Fort-Edward, on Hudſon River. Such was the ſavage ſtate of this part of the country, and the layers of trees laid lengthwiſe and acroſs, and ſo broken with creeks and marſhes, that General Burgoyne's army, in July, 1777, could ſcarcely advance above a mile in a day, on the road to Fort-Edward. They had no fewer than 40 bridges to conſtruct, one of which was of log work 2 miles in length; circumſtances which in after ages will appear hardly credible.—*ib.*

ANSON, an interior county of N. Carolina, in Fayette diſtrict, having Mecklinburg county N. and Bladen and Cumberland counties on the E. It contains 5133 inhabitants, including 828 ſlaves.—*ib.*

ANTECEDENTAL CALCULUS. See CALCULUS in this Supplement.

ANTES, in architecture, ſmall pilaſtres placed at the corners of buildings.

ANTHONY's FALLS, ST. in the River Miſſiſſippi, lie about 10 miles N. W. of the mouth of St. Pierre River, which joins the Miſſiſſippi from the W. and are ſituated in about lat. 44. 50. N. and were ſo named by father Louis Hennipin, who travelled into theſe parts about the year 1680, and was the firſt European ever ſeen by the natives there. The whole river, 250 yards wide, falls perpendicularly above 30 feet, and forms a moſt pleaſing cataract. The rapids below, in the ſpace of 300 yards, render the deſcent conſiderably greater; ſo that when viewed at a diſtance, they appear to be much higher than they really are. In the middle of the falls is a ſmall iſland, about 40 feet broad, and ſomewhat longer, on which grow a few hemlock and ſpruce trees; and about half way between this iſland and the eaſtern ſhore, is a rock, lying at the very edge of the fall, in an oblique poſition, 5 or 6 feet broad, and 30 or 40 long. Theſe falls are peculiarly ſituated, as they are approachable without the leaſt obſtruction from any intervening hill or precipice; which cannot be ſaid, perhaps, of any other conſiderable fall in the world. The ſcene around is exceedingly beautiful. It is not an uninterrupted plain, where the eye finds no relief, but compoſed of many gentle aſcents, which, in the ſpring and ſummer, are covered with verdure, and interſperſed with little groves, that give a pleaſing variety to the proſpect.

At a little diſtance below the falls is a ſmall iſland, about 1½ acre, on which grow a great number of oak trees, all the branches of which, able to bear the weight, are, in the proper ſeaſon of the year, loaded with eagles neſts. Their inſtinctive wiſdom has taught them to chooſe this place, as it is ſecure, on account of the rapids above, from the attacks either of man or beaſt.—*Morſe.*

ANTHONY's *Kill*, a weſtern water of Hudſon River. Its mouth is 7 miles above that of Mohawk River, with which likewiſe it communicates at the E. end of Long Lake.—*ib.*

ANTHONY's *Noſe*, a point of land in the Highlands, on Hudſon River, in the ſtate of New-York, from which to Fort Montgomery on the oppoſite ſide, a large boom and chain was extended in the late war, which coſt not leſs than 70,000l. ſterling. It was partly deſtroyed and partly carried away by General Sir Henry Clinton, in October, 1777. Alſo, the name given to the point of a mountain on the N. bank of Mohawk River, about 30 miles above Schenectady. Around this point runs the ſtage road.—*ib.*

ANTICS, in architecture, figures of men and animals placed as ornaments to buildings.

ANTICUM, in architecture, a porch; alſo that part of a temple which lies between the body of the temple and the portico, and is therefore called the outer temple.

ANTIETAM *Creek*, in Maryland, riſes by ſeveral branches in Pennſylvania, and empties into Potowmack River, 3 miles S. S. E. from Sharpſburg. Elizabeth and Funk's towns ſtand on this creek. It has a number of mills and forges.—*Morſe.*

ANTIMETER, or REFLECTING SECTOR, an inſtrument invented by Mr William Garrard, for the purpoſe of meaſuring angles, particularly ſmall ones, with a greater degree of accuracy than can be done by Hadley's quadrant or by the ſextant.

The frame of this inſtrument is ſimilar to that of Hadley's quadrant, having two radii, a limb, and braces; but with this difference, that the further radius is produced upwards of four inches beyond the centre of motion of the index; and the great ſpeculum, or what is called the index-glaſs in Hadley's quadrant, being placed there, is called the *upper centre*. In this inſtrument there is no proviſion for the back obſervation. The horizon-glaſs is like that in Hadley's quadrant; there are two ſight vanes, to ſuit two different ſituations of the large ſpeculum or object glaſs: theſe vanes are adapted to receive a ſmall teleſcope. On the centre of the index, where the index-glaſs of Hadley's quadrant is fixed, is a braſs or bell-metal ſemicircle, two inches in diameter, and one-eighth of an inch thick: this ſemicircle is ſcrewed faſt to the index, in ſuch a manner that the axis of the index is a tangent to it. On the upper centre are two circular braſs plates, which revolve concentrically, either together or ſeparately. The under plate has a lever, or part perpendicular to the plane of the inſtrument, projecting downwards, a little beyond the lower centre: this lever is acted upon by the ſemicircular plate at the lower centre, to which it is always kept cloſe by a ſpring on the other ſide. In the upper of the above mentioned circular plates are two circular perforations or ſlits, through one of which a ſcrew takes into the head of the inſtrument, and thro' the other a ſcrew takes into the lower moveable plate. The large ſpeculum is faſtened to the upper plate; and by the above mentioned ſcrews the poſition of this glaſs may be altered. A circular plate is fixed to the lower centre by three pillars: in its centre is a nut to admit a ſcrew, by which the plate carrying the large ſpeculum may be faſtened here occaſionally.

The ſcale on the limb is divided into 45 equal parts or degrees, and not into half degrees as is the caſe in Hadley's quadrant, by reaſon of the double reflection. Theſe diviſions are numbered in a retrogade order; zero being at the extremity of the further radius. Although the limb contains 45 degrees, yet the greateſt angle which can be meaſured, the large ſpeculum remaining fixed to the circular plate, is 10° 18′ 21″.8; the diſtance between the two centres being four inches, and the radius of the ſemicircle one inch. Agreeable to theſe dimenſions, the inventor has given a table exhibiting the value of each primary diviſion on the limb; he hath alſo given a more ample table, adapted to a diſtance between the centres of three times the radius of the ſemicircle, which he ſays hath been found the moſt convenient in practice. If an angle greater than 10° 18′ is wanted, it may be meaſured by the method of *anticipation*, as the inventor calls it, which is as follows: Let the ſcrew which faſtens the two circular plates on the upper centre be made faſt, and looſen the ſcrew which faſtens the upper circular plate to the inſtrument: Now adjuſt the glaſſes by the uſual method; bring forward the index to any given diviſion on the limb, and make it faſt; alſo faſten the ſcrew which was before looſe, and looſen the other ſcrew; then bring the index to zero, and proceed as before.

The inventor gives the following directions for adjuſting and uſing the inſtrument.

The firſt thing to be attended to is, to ſet the horizon-glaſs perpendicular to the plane of the inſtrument, which is performed as follows: Hold the inſtrument with its plane perpendicular to the horizon, and look over backwards into the glaſs and beyond it. If the limb of the inſtrument appears in a right line with its reflection, the glaſs is upright; but if it does not appear ſo, looſen or tighten the little ſcrew on the foot of the glaſs until it be adjuſted: Then with the inſtrument, as in taking an altitude, look through the ſight vane or teleſcope at ſome diſtant object, with the index fixed in any intended ſituation; the two ſcrews at the upper centre being looſe, turn the glaſs about till the ſame object appears nearly in the ſame part of the horizon-glaſs: Next hold it in a horizontal poſition, and adjuſt the object-glaſs or large ſpeculum with the ſcrews which are behind and before, on the foot of it, till the object and its reflection are ſeen in the ſame horizontal line. Laſtly, with the inſtrument upright, turn the tangent-ſcrew belonging to the horizon-glaſs at the back of the inſtrument, until there be a perfect coincidence of the object and its reflection that way, and the adjuſtments are complete.

ANTIPARALLELS, in geometry, are thoſe lines which make equal angles with two other lines, but contrary ways; that is, calling the former pair the firſt and ſecond lines, and the latter pair the third and fourth lines, if the angle made by the firſt and third lines be equal to the angle made by the ſecond and fourth, and contrariwiſe the angle made by the firſt and fourth equal to the angle made by the ſecond and third; then each pair of lines are antiparallels with reſpect to each other, viz. the firſt and ſecond, and the third and fourth. So, if AB and AC be any two lines, and FC and FE be two others, cutting them ſo,

that the angle B is equal to the angle E,
and the angle C is equal to the angle D;

then BC and DE are antiparallels with reſpect to AB and AC; alſo theſe latter are antiparallels with regard to the two former. It is a property of theſe lines, that each pair cuts the other into proportional ſegments, taking them alternately,

viz. AB : AC : : AE : AD : : DB : EC,
and FE : FC : : FB : FD : : DE : BC.

Plate II. fig. 5.

ANTONIO De Suchitepec, St. a town in Mexico or New Spain, on the coaſt of the Pacific Ocean. N. lat. 15. W. long. 93 5.—*Morſe.*

Antonio, St. the capital of the province of Apachiera, in New-Mexico.—*ib.*

Antonio, a town in the province of Navarre, in North-America, on a river which runs S. W. into the Gulph of California.—*ib.*

Antonio, Cape St. the moſt weſtern point of the iſland of Cuba; having on the N. W. a number of iſlets and rocks, called Los Colorados, between which and the cape is the channel of Guaniguanica. N. lat. 22. 15. W. long. 85½.—*ib.*

Antonio De Cabo, St. a town in Brazil, in South-America, near Cape St. Auguſtine, ſubject to the Portugueſe. Here they make a conſiderable quantity of ſugar. S. lat. 8. 34. W. long. 35. 22.—*ib.*

Antonio St. a town in New-Mexico, on the W. ſide of Rio Bravo River, below St. Gregoria. Alſo, the name of a town on the river Hondo, which falls into the Gulf of Mexico, N. E. of Rio de Brava; and on the eaſtern ſide of the river, S. by W. from Texas.—*ib.*

ANTERIM, a townſhip in Hillſborough county, New-Hampſhire, having 528 inhabitants, incorporated in 1777; 75 miles W. of Portſmouth, and about the ſame diſtance N. W. of Boſton.—*ib.*

ANVILLE, or *Miller's Town*, in Dauphine county, Pennſylvania, at the head of Tulpehocken Creek. When the canal between the Suſquehannah and Schuylkill, along theſe creeks, is completed, this town will probably riſe to ſome conſequence. It lies 18 miles N. E. by E. from Harriſburg, and 65. N. W. from Philadelphia.—*ib.*

ANZERMA, is a town and province of Popayan, in South-America, having mines of gold. It is ſeated on the river Coca. N. lat. 4. 58.—*ib.*

APACHIERA, an audience and province of New-Mexico, whoſe capital is St. Fe, in N. lat. 36. 30. W. long. 104.—*ib.*

APALACHES or *St. Mark's R.* riſes in the country of the Seminole Indians, in E. Florida, in N. lat. 31. 30. near the N. W. ſource of Great Satilla River; runs S. W through the Apalachy country, into the bay of Apalachy, in the Gulph of Mexico, about 15 miles below St. Mark's. It runs about 135 miles, and falls into the Bay near the mouth of Apalachicola River.—*ib.*

APALACHICOLA, a river between E. and W.

Florida, having its ſource in the Apalachian Mountains, in the Cherokee country, within ten miles of Tuguloo, the upper branch of Savannah River. From its ſource to the mouth of Flint River, a diſtance of 300 miles, it is called Chata-Uche, or Chatahooche River. Flint River falls into it from the N. E. below the Lower Creek Towns, in N. lat. 31. From thence it runs near 80 miles and falls into the Bay of Apalachy, or Apalachicola, in the Gulf of Mexico, at Cape Blaize. From its ſource to the 33d deg. of N. lat. its courſe is S. W. from thence to its mouth it runs nearly S. See *Chata-Ucha* and *Flint Rivers*.—*ib.*

Apalachicola, is likewiſe the name of the mother town or capital of the Creek or Muſcogulge confederacy, called Apalachucla by Bartram. It is, ſays he, ſacred to peace; no captives are put to death or human blood ſpilt here: and when a general peace is propoſed, deputies from all the towns in the confederacy meet here to deliberate. On the other hand, the great Coweta Town, 12 miles higher up the Chata-Uche River, is called the *Bloody Town*, where the Micos chiefs and warriors aſſemble when a general war is propoſed; and there captives and ſtate malefactors are put to death. Apalachicola is ſituated a mile and an half above the ancient town of that name, which was ſituated on a peninſula formed by the doubling of the river, but deſerted on account of inundations. The town is about 3 days journey from Tallaſſee, a town on the Tallapooſe River, a branch of the Mobile River. See *Coweta*, and *Tallaſſee*.—*ib.*

APALACHY *Country*, extends acroſs Flint and Apalaches Rivers, in Eaſt-Florida, having the Seminole country on the N. E. Apalachy, or Apalachya, is by ſome writers, applied to a town and harbour in Florida, 90 miles E. of Penſacola, and the ſame diſtance W. from Del Spiritu Santo River. The tribes of the Apalachian Indians lie around it.—*ib.*

APERTURE, in optics, has been defined in the Encyclopædia, but no rule was given there for finding a juſt aperture. As much depends upon this circumſtance, our optical readers will be pleaſed with the following practical rule given by Dr Hutton in his Mathematical Dictionary. "Apply ſeveral circles of dark paper, of various ſizes, upon the face of the glaſs, from the breadth of a ſtraw to ſuch as leave only a ſmall hole in the glaſs; and with each of theſe, ſeparately, view ſome diſtant object, as the moon, ſtars, &c. then that aperture is to be choſen through which they appear the moſt diſtinctly.

"Huygens firſt found the uſe of apertures to conduce much to the perfection of teleſcopes; and he found by experience (*Diopt.* prop. 56.), that the beſt aperture for an object-glaſs, for example of 30 feet, is to be determined by this proportion, as 30 to 3, ſo is the ſquare root of 30 times the diſtance of the focus of any lens to its proper aperture: and that the focal diſtances of the eye-glaſſes are proportioned to the apertures. And M. Auzout ſays he found, by experience, that the apertures of teleſcopes ought to be nearly in the ſubduplicate ratio of their lengths. It has alſo been found by experience, that object-glaſſes will admit of greater apertures, if the tubes be blacked within ſide, and their paſſage furniſhed with wooden rings.

"It is to be noted, that the greater or leſs aperture of an object-glaſs, does not increaſe or diminiſh the viſible area of the object; all that is effected by this is the admittance of more or fewer rays, and conſequently the more or leſs bright the appearance of the object. But the largeneſs of the aperture or focal diſtance cauſes the irregularity of its refractions. Hence, in viewing Venus through a teleſcope, a much leſs aperture is to be uſed than for the moon, or Jupiter, or Saturn, becauſe her light is ſo bright and glaring. And this circumſtance ſomewhat invalidates and diſturbs Azout's proportion, as is ſhown by Dr Hook, Phil. Tranſ. N° 4."

APOCATASTASIS, or, as it ſhould be written, Apokatastasis, is a Greek word employed in the language of aſtronomers, to denote the period of a planet, or the time it takes to return to that point of the zodiac whence it ſet out.

APOQUENEMY *Creek*, falls into Delaware Bay from Middletown, in New-caſtle county, Delaware, a mile and an half below Reedy Iſland. A canal is propoſed to extend from the ſouthern branch of this creek, at about 4 miles from Middletown, to the head of Bohemia River, nearly 8 miles diſtant; which will form a water communication between Delaware Bay, and that of Cheſapeak, through Elk River.—*ib.*

APPLE *Iſland*, a ſmall uninhabited iſland in St. Lawrence River, in Canada, on the S. ſide of the river, between Baſque and Green Iſlands. It is ſurrounded by rocks, which renders the navigation dangerous.—*ib.*

Apple *Town*, an Indian village on the E. ſide of Seneca Lake, in New-York, between the townſhips of Ovid on the S. and Romulus on the N.—*ib.*

APPOMATOX, is the name of a ſouthern branch of James River, in Virginia. It may be navigated as far as Broadways, 8 or 10 miles from Bermuda Hundred, by any veſſel which has croſſed Harriſon's Bar, in James River. It has 8 or 9 feet water a mile or two farther up to Fiſher's Bar, and 4 feet on that and upwards to Peterſburg, where all navigation ceaſes.—*ib.*

APOLO BAMA, a juriſdiction conſiſting of miſſions belonging to the Franciſcans, ſubject to the biſhop of Cuſco, 60 leagues from that city, in the empire of Peru. Theſe conſiſt of 7 towns of converted Indians. To protect theſe from the inſults of the other Indians, and to give credit to the miſſionaries, a militia is kept here, under a major-general, formed by the inhabitants.—*ib.*

APOTOME, is a term employed by Euclid to denote the difference between two lines or quantities which are only commenſurable in power. Such is the difference between 1 and $\sqrt{2}$, or the difference between the ſide of a ſquare and its diagonal. The doctrine of apotomes in lines, as delivered by this ancient mathematician in the tenth book of his Elements, is a very curious ſubject, and has always been admired by ſuch as underſtood it. The firſt algebraical writers in Europe, ſuch as Lucas de Burgo, Cardan, Tartalea, Stifelius, &c. employed a conſiderable portion of their works on an algebraical expoſition of that which led them to the doctrine of ſurd quantities.

APPARENT conjunction of the planets, is when a right line ſuppoſed to be drawn through their centres, paſſes through the eye of the ſpectator, and not through the centre of the earth. And, in general, the apparent conjunction of any objects, is when they appear or are placed in the ſame right line with the eye.

Apparent Diameter of a planet or other heavenly body, is not the real length of the diameter of that body, but the angle which it ſubtends at the eye, or under which it appears.

Apparent Diſtance, is that which we judge an object to be from us, when ſeen afar off; and which is almoſt always very different from the true diſtance.

Apparent Figure, is the figure or ſhape under which an object appears when viewed at a diſtance; and is often very different from the true figure. Thus a ſtraight line, viewed at a diſtance, may appear but as a point; a ſurface, as a line; and a ſolid, as a ſurface.

Apparent Motion, is either that motion which we perceive in a diſtant body that moves, the eye at the ſame time being either in motion or at reſt; or that motion which an object at reſt ſeems to have, while the eye itſelf only is in motion.

Apparent Place of a Planet, &c. in aſtronomy, is that point in the ſurface of the ſphere of the world where the centre of the luminary appears from the ſurface of the earth.

APPARITION, in aſtronomy, denotes a ſtar's or other luminary's becoming viſible, which before was hid. So, the heliacal riſing, is rather an apparition than a proper riſing.

APURIMA, or *Aporamac*, a very rapid river in Peru, South-America, 30 miles from the river Abanzai.—*Morse.*

AQUAFORT, a ſettlement on the E. ſide of the ſouth-eaſtern extremity of Newfoundland Iſland, lat. 47. 10. N.—*ib.*

AQUEDOCHTON, the outlet of lake Winnipiſeogee, in New-Hampſhire, N. lat. 43. 40. whoſe waters paſs through ſeveral ſmaller ones in a S. W. courſe, and empty into Merrimack River, between the towns of Sanburn and Canterbury.—*ib.*

ARARAT, *Mount* or the *Stone Head*, a ſhort range of mountains on the N. frontier of North-Carolina, in a N. E. direction from Ararat River, a N. W. branch of Yadkin River.—*ib.*

ARATHAPESCOW, an Indian tribe inhabiting the ſhores of the lake and river of that name, in the N. W. part of North-America, between the latitudes of 57. and 59. N. North of this nation's abode, and near the Arctic Circle, is Lake Edlande, around which live the Dog Ribbed Indians.—*ib.*

ARAUCO, a fortreſs and town of Chili, in South-America; ſituated in a fine valley, on a river of the ſame name, N. by W. from Baldivia. The native Indians are ſo brave that they drove the Spaniards out of their country, though deſtitute of fire-arms. S. lat. 37. 30. W. long. 73. 20.—*ib.*

ARAZIBO, one of the principal places in Porto Rico Iſland, in the Weſt-Indies. It has few inhabitants, and little trade but ſmuggling.—*ib.*

ARCAS, an iſland in the Gulf of Mexico, in the Bay of Campeachy. Lat. 20. long. 92. 50.—*ib.*

1 Arch defined.

ARCH, in building, is an artful diſpoſition and adjuſtment of ſeveral ſtones or bricks, generally in a bow-like form, by which their weight produces a mutual preſſure and abutment; ſo that they not only ſupport each other, and perform the office of an entire lintel, but may be extended to any width, and made to carry the moſt enormous weights.

2 Hiſtory of architecture connected with arches.

In thoſe mild climates which ſeem to have been the firſt inhabited parts of this globe, mankind ſtood more in need of ſhade from the ſun than of ſhelter from the inclemency of the weather. A very ſmall addition to the ſhade of the woods ſerved them for a dwelling. Sticks laid acroſs from tree to tree, and covered with bruſhwood and leaves, formed the firſt houſes in thoſe delightful regions. As population and the arts improved, theſe huts were gradually refined into commodious dwellings. The materials were the ſame, but more artfully put together. At laſt agriculture led the inhabitants out of the woods into the open country. The connection between the inhabitant and the ſoil became now more conſtant and more intereſting. The wiſh to preſerve this connection was natural, and fixed eſtabliſhments followed of courſe. Durable buildings were more deſirable than thoſe temporary and periſhable cottages—ſtone was ſubſtituted for timber.

But as theſe improved habitations were gradual refinements on the primitive hut, traces of its conſtruction remained, even when the choice of more durable materials made it in ſome meaſure inconvenient. Thus it happened, that while a plain building, intended for accommodation only, conſiſted of walls, pierced with the neceſſary doors and windows, an ornamented building had, ſuperadded to theſe eſſentials, columns, with the whole apparatus of entablature, borrowed from the wooden building, of which they had been eſſential parts, gradually rendered more ſuitable to the purpoſes of accommodation and elegance.

3 Origin of Greek architecture.

This view of ornamental architecture will go far to account for ſome of the more general differences of national ſtyle which may be obſerved in different parts of the world. The Greeks borrowed many of their arts from their Aſiatic neighbours, who had cultivated them long before. It is highly probable that architecture travelled from Perſia into Greece. In the ruins of Shuſhan, Perſepolis, or Tchilminar, are to be ſeen the firſt models of every thing that diſtinguiſhes the Grecian architectures. There is no doubt, we ſuppoſe, among the learned, as to the great priority of theſe monuments to any thing that remains in Greece; eſpecially if we take into account the tombs on the mountains, which have every appearance of greater antiquity than the remains of Perſepolis. In thoſe tombs we ſee the whole *ordonnance* of column and entablature, juſt as they began to deviate from their firſt and neceſſary forms in the wooden buildings. We have the architrave, frize, and corniche; the far-projecting mutules of the Tuſcan and Doric orders; the modillions no leſs diſtinct; the rudiments of the Ionic capital; the Corinthian capital in perfection, pointing out the very origin of this ornament, viz. a number of long graceful leaves tied round the head of the column with a fillet (a cuſtom which we know to have been common in their temples and banqueting rooms). Where the diſtance between the columns is great, ſo that each had to ſupport a weight too great for one tree, we ſee the columns cluſtered or fluted, &c. In ſhort, we ſee every thing of the Grecian architecture but the ſloped roof or pediment; a thing not wanted in a country where it hardly ever rains.

4 Egyptian,

The ancient Egyptian architecture ſeems to be a refinement on the hut built of clay, or unburnt bricks mixed with ſtraw—every thing is maſſive, clumſy, and timid—ſmall intercolumnations, and hardly any projections.

5 Arabian, and

The Arabian architecture ſeems a refinement on the tent. A moſque is like a little camp, conſiſting of a number of little bell tents, ſtuck cloſe together round a great one. A caravanſeray is a court ſurrounded by a row of ſuch tents, each having its own dome. The Greek church of St Sophia at Conſtantinople has imitated this in ſome degree; and the copies from it, which have been multiplied in Ruſſia as the ſacred form for a Chriſtian church, have adhered to the original model of cluſtered tents in the ſtricteſt manner. We are ſometimes diſpoſed to think that the painted glaſs (a faſhion brought from the Eaſt) was an imitation of the painted hangings of the Arabs.

6 Chineſe architecture.

The Chineſe architecture is an evident imitation of a wooden building. Sir Geo. Staunton ſays, that the ſingular form of their roofs is a *profeſſed* imitation of the cover of a ſquare tent.

In the ſtone-buildings of the Greeks, the roofs were imitations of the wooden ones; hence the lintels, flying corniches, ceilings in compartments, &c.

Plate I. 7 Origin of the arch.

The pediment of the Greeks ſeems to have ſuggeſted the greateſt improvement in the art of building. In erecting their ſmall houſes, they could hardly fail to obſerve occaſionally, that when two rafters were laid together from the oppoſite walls, they would, by leaning on each other, give mutual ſupport, as in fig. 1. Nor is it unlikely that ſuch a ſituation of ſtones as is repreſented in fig. 2. would not unfrequently occur by accident to maſons. This could hardly fail of exciting a little attention and reflection. It was a pretty obvious reflection, that the ſtones A and C, by overhanging, leaned againſt the intermediate ſtone B, and gave it ſome ſupport, and that B cannot get down without thruſting aſide A and C, or the piers which ſupport them. This was an approach to the theory of an arch; and if this be combined with the obſervation of fig. 1. we get the diſpoſition repreſented in fig. 3. having a perpendicular joint in the middle, and the *principle of the arch* is completed. Obſerve that this is quite different from the principle of the arrangement in fig. 2. In that figure the ſtones act as wedges, and one cannot get down without thruſting the reſt aſide; the ſame principle obtains in fig. 4. conſiſting of five arch ſtones; but in fig. 3. the ſtones B and C ſupport each other by their mutual preſſure (independent of their own weight), ariſing from the tendency of each lateral pair to fall outwards from the pier. This is the principle of the arch, and would ſupport the key-ſtone of fig. 4. although each of its joints were perpendicular, by reaſon of the great friction ariſing from the horizontal thruſt exerted by the adjoining ſtones.

This was a moſt important diſcovery in the art of building; for now a building of any width may be roofed with ſtone.

8 Grecian.

We are diſpoſed to give the Greeks the merit of this diſcovery; for we obſerve arches in the moſt ancient buildings of Greece, ſuch as the temple of the ſun at Athens, and of Apollo at Didymos; not indeed as roofs to any apartment, nor as parts of the ornamental deſign, but concealed in the walls, covering drains or other neceſſary openings; and we have not found any *real* arches in any monuments of ancient Perſia or Egypt. Sir John Chardin ſpeaks of numerous and extenſive ſubterranean paſſages at Tchelminar, built of the moſt exquiſite maſonry, the joints ſo exact, and the ſtones ſo beautifully dreſſed, that they look like one continued piece of poliſhed marble; but he nowhere ſays that they are arched; a circumſtance which we think he would not have omitted—no arched door or window is to be ſeen. Indeed one of the tombs is ſaid to be arch-roofed, but it is all of one ſolid rock. No trace of an arch is to be ſeen in the ruins of ancient Egypt; even a wide room is covered with a ſingle block of ſtone. In the pyramids, indeed, there are two galleries, whoſe roofs conſiſt of many pieces; but their conſtruction puts it beyond doubt that the builder did not know what an arch was: for it is covered in the manner repreſented in fig. 5. where every projecting piece is more than balanced behind, ſo that the whole aukward maſs could have ſtood on two pillars. The Greeks therefore ſeem entitled to the honour of the invention. The arched dome, however, ſeems to have ariſen in Etruria, and originated in all probability from the employment of the augurs, whoſe buſineſs it was to obſerve the flight of birds. Their ſtations for this purpoſe were *templa*, ſo called *a templando*, "on the ſummits of hills." To ſhelter ſuch a perſon from the weather, and at the ſame time allow him a full proſpect of the country around him, no building was ſo proper as a dome ſet on columns; which accordingly is the figure of a temple in the moſt ancient monuments of that country. We do not recollect a building of this kind in Greece except that called the *Lanthern of Demoſthenes*, which is of very late date, whereas they abounded in Italy. In the later monuments and coins of Italy or of Rome, we commonly find the Etruſcan dome and the Grecian temple combined; and the famous pantheon was of this form, even in its moſt ancient ſtate.

9 It was uſed at firſt only in bridges and aqueducts.

It does not appear that the arch was conſidered as a part of the *ornamental* architecture of the Greeks during the time of their independency. It is even doubtful whether it was employed in roofing their temples. In none of the *ancient* buildings where the roof is gone, can there be ſeen any rubbiſh of the vault, or mark of the ſpring of the arch. It is not unfrequent, however, after the Roman conqueſts, and may be ſeen in Athens, Delos, Palmyra, Balbek, and other places. It is very frequent in the magnificent buildings of Rome; ſuch as the Coliſeum, the baths of Diocleſian, and the triumphal arches, where its form is evidently made the object of attention. But its chief employment was in bridges and aqueducts; and it is in thoſe works that its immenſe utility is the moſt conſpicuous: For by this happy contrivance a canal or a road may be carried acroſs any ſtream, where it would be almoſt impoſſible to erect piers ſufficiently near to each other for carrying lintels. Arches have been executed 130 feet wide, and their execution demonſtrates that they may be made four times as wide.

10 Difficulty of conſtructing it.

As ſuch ſtupendous arches are the greateſt performances of the maſonic art, ſo they are the moſt difficult and delicate. When we reflect on the immenſe quantity of materials thus ſuſpended in the air, and compare this with the ſmall coheſion which the firmeſt cement can give to a building, we ſhall be convinced that it is not by the force of the cement that they are kept together: they ſtand faſt only in conſequence of the proper balance of all their parts. Therefore, in order

to

the buttreſs which was to withſtand theſe thruſts muſt not be placed on the ſouth ſide of the pier, but on the ſouth-eaſt ſide, or that there muſt be an eaſtern as well as a ſouthern buttreſs. 15 Such as are never found in a Gothic church. No ſuch blunders are to be ſeen in a Gothic cathedral. Some of them appear, to a careleſs ſpectator, to be very maſſive and clumſy; but when judiciouſly examined, they will be found very bold and light, being pierced in every direction by arcades, and the walls are divided into cells like a honeycomb, ſo that they are very ſtiff, while they are very light.

About the middle, or rather towards the end, of laſt century, when the Newtonian mathematics opened the road to true mechanical ſcience, the conſtruction of arches engroſſed the attention of the firſt mathematicians. 16 Dr Hooke's principle of arches The firſt hint of a principle that we have met with is Dr Hooke's aſſertion, that the figure into which a chain or rope, perfectly flexible, will arrange itſelf when ſuſpended from two hooks, is, when inverted, the proper form for an arch compoſed of ſtones of uniform weight. This he affirmed on the ſame principle which is made uſe of in the Encyclopædia in the article Roof, § 25. viz. that the figure which a flexible feſtoon of heavy bodies aſſumes, when ſuſpended from two points, is, when inverted, the proper form for an arch of the ſame bodies, touching each other in the ſame points; becauſe the forces with which they mutually preſs on each other in this laſt caſe, are equal and oppoſite to the forces with which they pull at each other in the caſe of ſuſpenſion.

This principle is ſtrictly juſt, and may be extended to every caſe which can be propoſed. We recollect ſeeing it propoſed, in very general terms, in the St. James's Chronicle in 1759, when plans were forming for Blackfriar's Bridge in London; and ſince it is perhaps equal, in practical utility, to the moſt elaborate inveſtigations of the mathematicians, our readers will not be diſpleaſed with a more particular account of it in this place.

17 Explained,

Let ABC (fig. 6.) be a parcel of magnets of any ſize and ſhape, and let us ſuppoſe that they adhere with great force by any points of contact. They will compoſe ſuch a flexible feſtoon as we have been ſpeaking of, if ſuſpended from the points A and C. If this figure be inverted, preſerving the ſame points of contact, they will remain in equilibrio. It will indeed be that kind of equilibrium which will admit of no diſturbance, and which may be called a *tottering equilibrium*. If the form be altered in the ſmalleſt degree, by varying the points of contact (which indeed are points in the *figure of equilibration*), the magnets will no more recover their former poſition than a needle, which we had made to ſtand on its point, will regain its perpendicular poſition after it has been diſturbed.

But if we ſuppoſe planes *d e*, *f g*, *h i*, &c. drawn, that the points of mutual contact *a*, *b*, *c*, each biſecting the angle formed by the lines that unite the adjoining contacts (*f g*, for example, biſecting the angle formed by *a b*, *b c*), and if we ſuppoſe that the pieces are changed for others of the ſame weights, but having flat ſides, which meet in the planes *d e*, *f g*, *h i*, &c. it is evident that we ſhall have an arch of equilibration, and that the arch will have ſome ſtability, or will bear a little change of form without tumbling down: for it is plain that the equilibrium of the original feſtoon obtained only in the points *a*, *b*, *c*, of contact, where the preſſures were perpendicular to the touching ſurfaces; therefore if the curve *a*, *b*, *c*, ſtill paſſes through the touching ſurfaces perpendicularly, the conditions that are required for equilibrium ſtill obtain. The caſe is quite ſimilar to that of the ſtability of a body reſting on a horizontal plane. If the perpendicular through the centre of gravity falls within the baſe of the body, it will not only ſtand, but will require ſome force to puſh it over. In the original feſtoon, if a ſmall weight be added in any part, it will change the form of the curve of equilibration a little, by changing the points of mutual contact. This new curve will gradually ſeparate from the former curve as it recedes from A or C. In like manner, when the feſtoon is ſet up as an arch, if a ſmall weight be laid on any part of it, it will bring the whole to the ground, becauſe the ſhifting of the points of contact will be juſt the contrary to what it ſhould be to ſuit the new curve of equilibration. But if the ſame weight be laid on the ſame part of the arch now conſtructed with flat joints, it will be ſuſtained, if the new curve of equilibration ſtill paſſes through the touching ſurfaces.

Theſe concluſions, which are very obviouſly deducible from the principle of the feſtoon, ſhew us, without any further diſcuſſion, that the longer the joints are, the greater will be the ſtability of the arch, or that it will require a greater force to break it down. Therefore it is of the greateſt importance to have the arch ſtones as long as economy will permit; and this was the great uſe of the ribs and other apparent ornaments in the Gothic architecture. The great projections of thoſe ribs augmented their ſtiffneſs, and enabled them to ſupport the unadorned copartments of the roof, compoſed of very ſmall ſtones, ſeldom above ſix inches thick. Many old bridges are ſtill remaining, which are ſtrengthened in the ſame way by ribs.

Having thus explained, in a very familiar manner, the ſtability of an arch, we proceed to give the ſame popular account of the general application of the principle.

18 And applied.

Suppoſe it to be required to aſcertain the form of an arch which ſhall have the ſpan AB (fig. 7.), and the height F 8, and which ſhall have a road-way of the dimenſions CDE above it. Let the figure ACDEB be inverted, ſo as to form a figure A *c d e* B. Let a chain of uniform thickneſs be ſuſpended from the points A and B, and let it be of ſuch a length that its lower point will hang at, or rather a little below, *f*, correſponding to F. Divide AB into a number of equal parts, in the points 1, 2, 3, &c. and draw vertical lines, cutting the chain in the correſponding points 1, 2, 3, &c. Now take pieces of another chain, and hang them on at the points 1, 2, 3, &c. of the chain A *f* B. This will alter the form of the curve. Cut or trim theſe pieces of chain, till their lower ends all coincide with the inverted road-way *c d e*. The greater lengths that are hung on in the vicinity of A and B will pull down theſe points of the chain, and cauſe the middle point *f* (which is leſs loaded) to riſe a little, and will bring it near to its proper height.

It is plain that this proceſs will produce an arch of perfect equilibration; but ſome farther conſiderations are neceſſary for making it exactly ſuit our purpoſe. It is an arch of equilibration for a bridge, that is ſo loaded that the weight of the arch ſtones is to the weight of the matter with which the haunches and crown are loaded, as the weight of the chain A *f* B is to a level; for the ſecant of CV is twice CO, and therefore C *c* is 8 times V *v*, which is $\frac{1}{7}$th of VH.

The dotted line *v g c f* is drawn according to this calculus or conſtruction. It falls conſiderably below the horizontal line in the neighbourhood of *c*; and then, paſſing very obliquely through *c*, it riſes rapidly to an unmeaſurable height, becauſe the vertical line through A is its aſſymptote. This muſt evidently be the caſe with every curve which ſprings at right angles with a horizontal line.

It is plain that if *v* V be greater, all the other ordinates of the curve *v g c f*, reſting on the circumference AVE, will be greater in the ſame proportion, and the curve will cut the horizontal line drawn through *v* in ſome point nearer to *v* than *c* is. Hence it appears that a circular arch cannot be put in equilibrio by building on it up to a horizontal line, whatever be its ſpan, or whatever be the thickneſs at the crown. We have ſeen that when this thickneſs is only $\frac{1}{14}$th of the radius, an arch of 120 degrees will be too much loaded at the flanks. This thickneſs is much too ſmall for a bridge, being only $\frac{1}{25}$th of the ſpan CM, whereas it ſhould have been almoſt double of this, to bear the inequalities of weight that may occaſionally be on it. When the crown is made ſtill thinner, the outline is ſtill more depreſſed before it riſes again. There is therefore a certain ſpan, with a correſponding thickneſs at the crown, which will deviate leaſt of all from a horizontal line. This is an arch of about 54 degrees, the thickneſs at the crown being about one-fourth of the ſpan, which is extravagantly great. It appears in general therefore, that the circle is not a curve ſuited to the purpoſes of a bridge or an arcade, which requires an outline nearly horizontal.

Examp. 2. Let the curve be a parabola AVE (fig. 11.), of which V is the vertex, and DG the directrix. Draw the diameters DCF, GVN, the tangent CK, VP, and the ordinates VF and CN. It is well known that GV is to DC as VP^2 to CK^2, or as CN^2 to CK^2. Alſo 2 GV is the radius of the oſculating circle at V, and 2 DC is one-half of the vertical cord of the oſculating circle at C. Therefore $CN^2 : CK^2$ (or $\dot{y}^2 : \dot{z}^2$) $= R : s$, and $s = \frac{\dot{z}^2}{\dot{y}^2}R$. But C *c*, or $h = H \times \frac{\dot{z}^2 R}{\dot{y}^2 S}$. Therefore

$$h = H \times \frac{\dot{z}^2 \quad R}{\dot{y}^2 \frac{\dot{z}^2}{\dot{y}^2} R}, \quad = H \times \frac{\dot{z}^2 R}{\dot{z}^2 R}, \quad = H. \quad \text{Therefore}$$

$Cc = vV$.

It follows from this inveſtigation, that the back or extrados of a parabolic arch of equilibration muſt be parallel to the arch or ſoffit itſelf; or that the thickneſs of the arch, eſtimated in a vertical direction, muſt be equal throughout; or that the extrados is the ſame parabola with the ſoffit or intrados.

We have ſelected theſe two examples merely for the ſimplicity and perſpicuity of the ſolutions, which have been effected by means of elementary geometry only, inſtead of employing the analytical value of the radius of the oſculatory circle viz. $\frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$, which would have involved us at leaſt in the elements of ſecond fluxions. We have alſo preferred ſimplicity to elegance in the inveſtigation, becauſe we wiſh to inſtruct the practical engineer, who may not be a proficient in the higher mathematics.

25 To find the form of an arch when the figure of its back is given.

The converſe of the problem, namely, to find the form of the arch when the figure of the back of it is given, is the moſt uſual queſtion of the two, at leaſt in caſes which are moſt important and moſt difficult. Of theſe perhaps bridges are the chief. Here the neceſſity of a road-way, of eaſy and regular aſcent, confines us to an outline nearly horizontal, to which the curve of the arch muſt be adapted. This is the moſt difficult problem of the two; and we doubt whether it can be ſolved without employing infinite approximating ſerieſes inſtead of accurate values.

Let *a v e* (fig. 12.) be the intended outline or extrados of the arch AVE, and let *v* Q be the common axis of both curves. From *c* and C, the correſponding points, draw the ordinates *c h*, CH. Let the thickneſs *v* V at the top be *a*, the abſciſſa *v h* be $= u$, and VH $= x$, and let the equal ordinates *c h*, CH be *y*, and the arch VC be *z*.

Then, by the general theorem, $cC = \frac{\dot{z}^3}{r\dot{y}^3}$, *r* being the radius of curvature. This, by the common rules, is $= \frac{\dot{z}^3}{\dot{y}\ddot{x} - \dot{x}\ddot{y}}$. This gives us $cC = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3}$, or $= \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times C$; where C is a conſtant quantity, found by taking the real value of *c* C in V, the vertex of the curve. But it is evident that it is alſo $= a + x - u$. Therefore $a + x - u = \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3} \times C, = \frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

If we now ſubſtitute the true value of *u* (which is given, becauſe the extrados is ſuppoſed to be of a known form), expreſſed in terms of *y*, the reſulting equation will contain nothing but *x* and *y*, with their firſt and ſecond fluxions, and known quantities. From this equation the relation of *x* and *y* muſt be found by ſuch methods as ſeem beſt adapted to the equation of the extrados.

Fortunately the proceſs is more ſimple and eaſy in the moſt common and uſeful caſe than we ſhould expect from this general rule. We mean the caſe where the extrados is a ſtraight line, eſpecially when this is horizontal. In this caſe *u* is equal to *o*.

Plate II.

Example. To find the form of the balanced arch AVE (fig. 13.), having the horizontal line *c v* for its extrados.

Keeping the ſame notation, we have $u = o$, and therefore $a + x = \frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$.

Aſſume $\dot{y} = \frac{\dot{x}}{v}$; then $\frac{\dot{x}}{\dot{y}} = v$, and $\frac{C}{\dot{y}} \times$ fluxion of $\frac{\dot{x}}{\dot{y}}$, $= \frac{Cv\dot{v}}{\dot{x}}$, that is $a + x = \frac{Cv\dot{v}}{\dot{x}}$. Therefore $a\dot{x} + x\dot{x} = Cv\dot{v}$; and by taking the fluents, we have $2ax + x^2 = Cv^2$; and $v = \sqrt{\frac{2ax + x^2}{C}}$. Conſequently,

$\dot{y} = \frac{\sqrt{C}\,\dot{x}}{\sqrt{2ax \times x^2}}\left(\text{being} = \frac{\dot{x}}{v}\right)$. Taking the fluent of this, we have $y = \sqrt{C} \times L\,(2ax + 2x^2 + 2\sqrt{2ax + x^2})$. But at the vertex, where $x = 0$, we have $y = \sqrt{C} \times L\,(2a)$. The corrected fluent is therefore $y = \sqrt{C} \times L\frac{a + x + \sqrt{2ax + x^2}}{a}$.

It only remains to find the conſtant quantity C. This we readily obtain by ſelecting ſome point of the extrados where the values of x and y are given by particular circumſtances of the caſe. Thus, when the ſpan $2s$ and height h of the arch are given, we have $s = \sqrt{C} \times L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)$, and conſequently $\sqrt{C} = \frac{s}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)}$. Therefore the general value of

$$y = s \times \frac{L\left(\frac{a + x + \sqrt{2ax + x^2}}{a}\right)}{L\left(\frac{a + h + \sqrt{2ah + h^2}}{a}\right)};$$

$$= \frac{s}{L\frac{a + h + \sqrt{2ah + h^2}}{a}} \times L\frac{a + x + \sqrt{2ax + x^2}}{a}.$$

As an example of the uſe of this formula, we ſubjoin a table calculated by Dr Hutton of Woolwich for an arch, the ſpan of which is 100 feet and the height 40, which are nearly the dimenſions of the middle arch of Blackfriars Bridge in London.

y	x	y	x	y	x
0	6,000	21	10,381	36	21,774
2	6,035	22	10,858	37	22,948
4	6,144	23	11,368	38	24,190
6	6,324	24	11,911	39	25,505
8	6,580	25	12,489	40	26,894
10	6,914	26	13,106	41	28,364
12	7,330	27	13,761	42	29,919
13	7,571	28	14,457	43	31,563
14	7,834	29	15,196	44	33,299
15	8,120	30	15,980	45	35,135
16	8,430	31	16,811	46	37,075
17	8,766	32	17,693	47	39,126
18	9,168	33	18,627	48	41,293
19	9,517	34	19,617	49	43,581
20	9,934	35	20,665	50	46,000

26
Defects of the Catenarian curve.

The figure for this propoſition is exactly drawn according to theſe dimenſions, that the reader may judge of it as an object of ſight. It is by no means deficient in gracefulneſs, and is abundantly roomy for the paſſage of craft; ſo that no objection can be offered againſt its being adapted on account of its mechanical excellency.

The reader will perhaps be ſurpriſed that we have made no mention of the celebrated Catenarean curve, which is commonly ſaid to be the beſt form for an arch; but a little reflection will convince him, that although it is the only form for an arch conſiſting of ſtones of equal weight, and touching each other only in ſingle points, it cannot ſuit an arch which muſt be filled up in the haunches, in order to form a road-way. He will be more ſurpriſed to hear, after this, that there is a certain thickneſs at the crown, which will put the Catenarea in equilibrio, even with a horizontal road-way; but this thickneſs is ſo great as to make it unfit for a bridge, being ſuch that the preſſure at the vertex is equal to the horizontal thruſt. This would have been about 37 feet in the middle arch of Blackfriars Bridge. The only ſituation therefore in which the Catenarean form would be proper, is an arcade carrying a height of dead wall; but in this ſituation it would be very ungraceful. Without troubling the reader with the inveſtigation, it is ſufficient to inform him that in a Catenarean arch of equilibration the abſciſſa VH is to the abſciſſa $v\,h$ in the conſtant ratio of the horizontal thruſt to its exceſs above the preſſure on the vertex.

27
Inutility of the common theory of equilibration.

This much will ſerve, we hope, to give the reader a clear notion of this celebrated theory of the equilibrium of arches, one of the moſt delicate and important applications of mathematical ſcience. Volumes have been written on the ſubject, and it ſtill occupies the attention of mechanicians. But we beg leave to ſay, with great deference to the eminent perſons who have proſecuted this theory, that their ſpeculations have been of little ſervice, and are little attended to by the practitioner. Nay, we may add, that Sir Chriſtopher Wren, perhaps the moſt accompliſhed architect that Europe has ſeen, ſeems to have thought it of little value: for, among the fragments which have been preſerved of his ſtudies, there are to be ſeen ſome imperfect diſſertations on this very ſubject, in which he takes no notice of this theory, and conſiders the balance of arches in quite another way. Theſe are collected by the author of the account of Sir Chriſtopher Wren's family. This man's great ſagacity, and his great experience in building, and, ſtill more his experience in the repairs of old and crazy fabrics, had ſhown him many things very inconſiſtent with this theory, which appears ſo ſpecious and ſafe. The general facts which occur in the failure of old arches are highly inſtructive, and deſerve the moſt careful attention of the engineer; for it is in this ſtate that their defects, and the proceſs of nature in their deſtruction, are moſt diſtinctly ſeen. We venture to affirm, that a very great majority of theſe facts are irreconcileable to the theory. The way in which circular arches commonly fail, is by the ſinking of the crown and the riſing of the flanks. It will be found by calculation, that in moſt of the caſes it ought to have been juſt the contrary. But the cleareſt proof is, that arches very rarely fail where their load differs moſt remarkably from that which this theory allows. Semicircular arches have ſtood the power of ages, as may be ſeen in the bridges of ancient Rome, and in the numerous arcades which the ancient inhabitants have erected. Now all arches which ſpring perpendicularly from the horizontal line, require, by this theory, a load of infinite height; and, even to a conſiderable diſtance from the ſpringing of the arch, the load neceſſary for the theoretical equilibrium is many times greater than what is ever laid on thoſe parts; yet a failure in the immediate neighbourhood of the ſpring of an arch is a moſt rare phenomenon, if it ever was obſerved. Here is a moſt remarkable deviation from the theory; for, as is already obſerved, the load is frequently not the fourth part of what the theory requires.

Many other facts might be adduced which ſhow great deviations

Fig. 1.

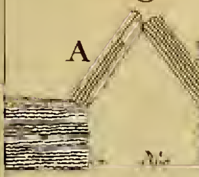


Fig. 2.

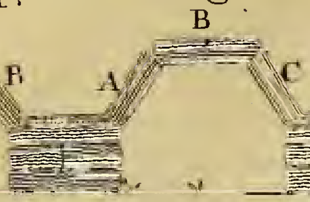


Fig. 3.

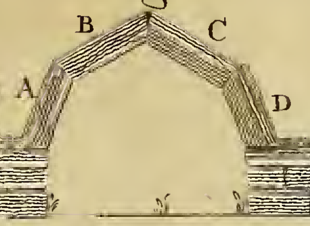


Fig. 4.

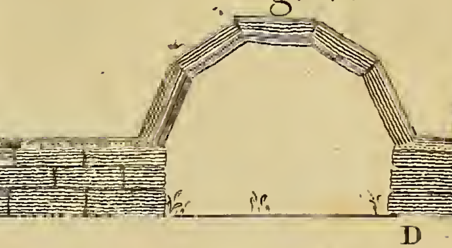


Fig. 5.

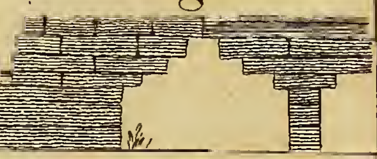


Fig. 6.

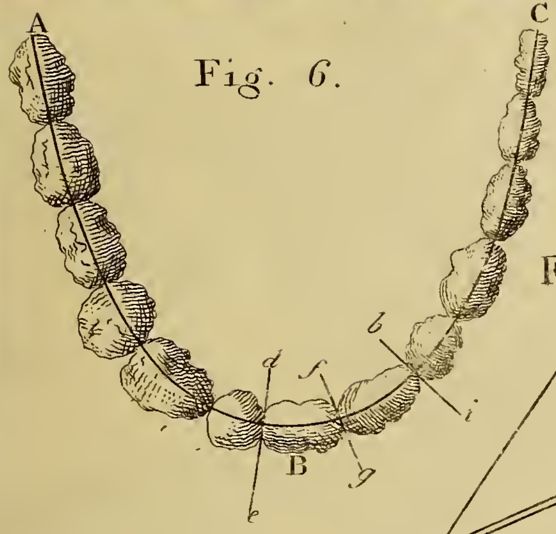


Fig. 7.

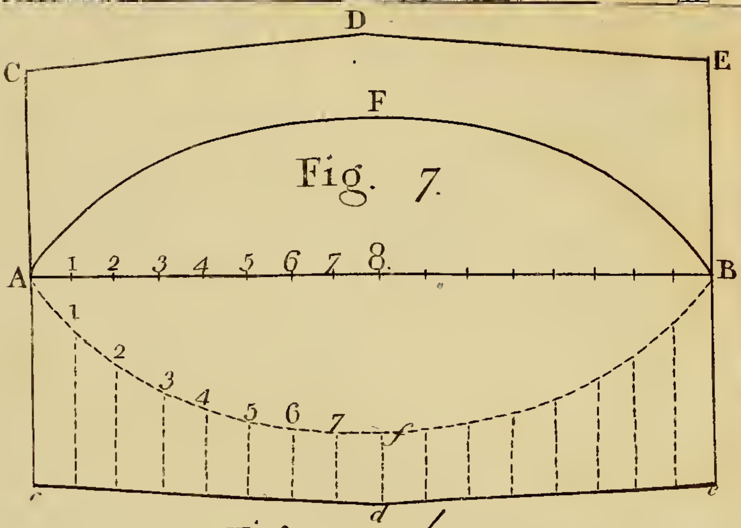


Fig. 8.

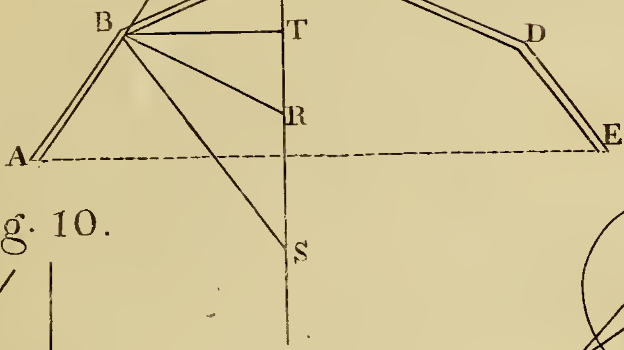


Fig. 9.

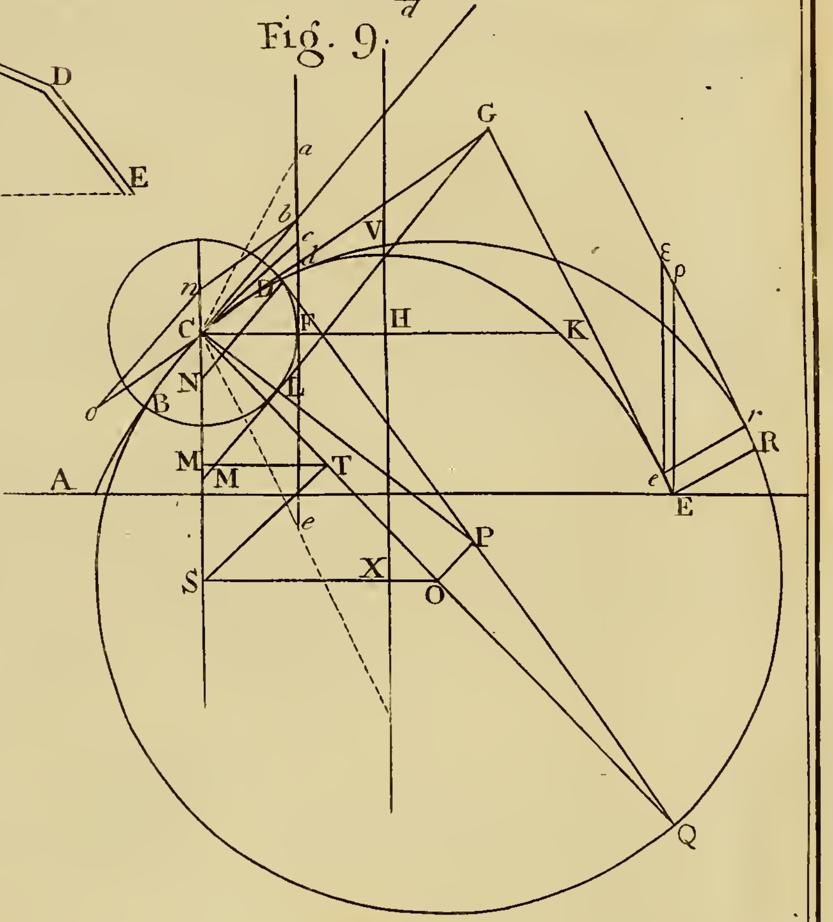


Fig. 10.

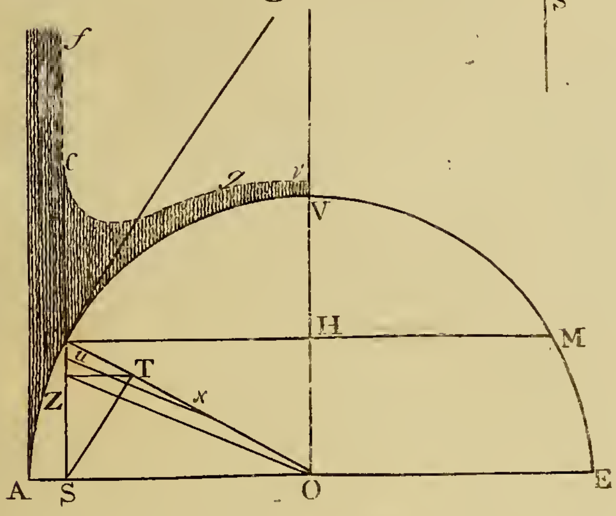


Fig. 11.

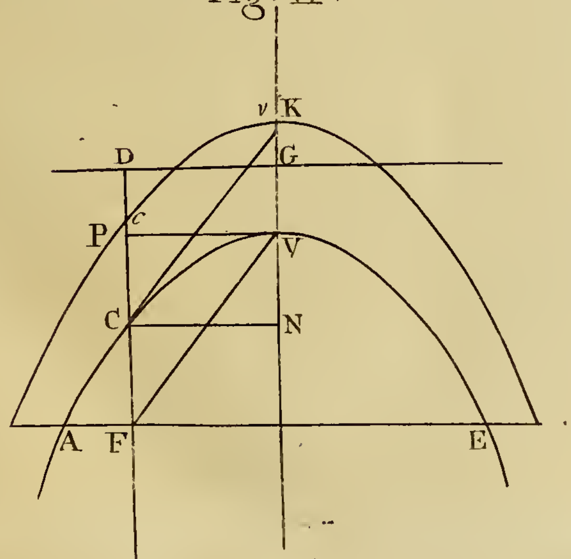
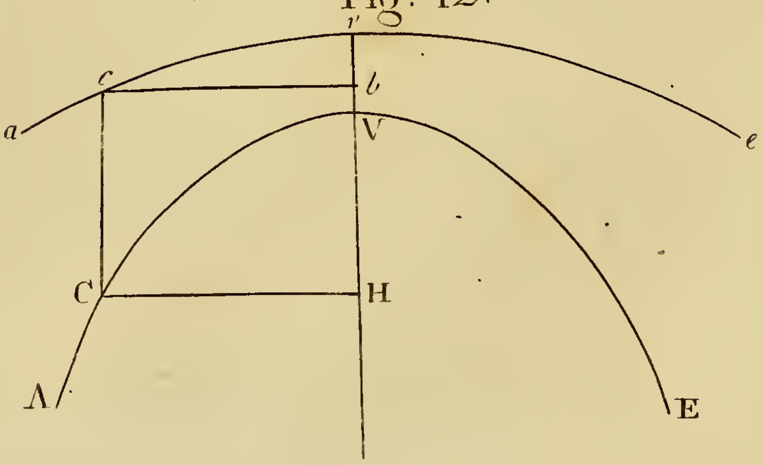


Fig. 12.



J. Bowyer sc.

28 Its defects.

deviations from the legitimate reſults from the theory. We hope to be excuſed, therefore, by the mathematicians for doubting of the juſtneſs of this theory. We do not think it erroneous, but defective, leaving out circumſtances which we apprehend to be of great importance; and we imagine that the defects of the theory have ariſen from the very anxiety of the mechanicians to make it perfect. The arch ſtones are ſuppoſed to be perfectly ſmooth or poliſhed, and not to be connected by any cement, and therefore to ſuſtain each other merely by the equilibrium of their vertical preſſure. The theory enſures this equilibrium, and this only, leaving unnoticed any other cauſes of mutual action.

The authors who have written on the ſubject ſay expreſsly, that an arch which thus ſuſtains itſelf muſt be ſtronger than another which would not; becauſe when, in imagination, we ſuppoſe both to acquire connection by cement, the firſt preſerves the influence of this connection unimpaired; whereas in the other, part of the coheſion is waſted in counteracting the tendency of ſome parts to break off from the reſt by their want of equilibrium. This is a very ſpecious argument, and would be juſt, if the forces which are mutually exerted between the parts of the arch in its ſettled ſtate were merely vertical preſſures, or, where different, were inconſiderable in compariſon with thoſe which are really attended to in the conſtruction.

But this is by no means the caſe. The forms which the uſes for which arches are erected oblige us to adopt, and the loads laid on the different points of the arch, frequently deviate conſiderably from what are neceſſary for the equilibrium of vertical preſſures. The varying load on a bridge, when a great waggon paſſes along it, ſometimes bears a very ſenſible proportion to the weight of that point of the arch on which it reſts. It is even very doubtful whether the preſſures which are occaſioned by the weight of the ſtuff employed for filling up the flanks really act in a vertical direction, and in the proportion which is ſuppoſed. We are pretty certain that this is not the caſe with ſand, gravel, fat mould, and many ſubſtances in very general uſe for this purpoſe. When this is the caſe, the preſſures ſuſtained by the different parts of the arch are often very inconſiſtent with the theory—a part of the arch is overloaded, and tends to fall in, but is prevented by the cement. This part of the arch therefore acts on the remoter parts by the intervention of the parts between, employing thoſe intermediate parts as a kind of levers to break the arch in a remote part, juſt as a lintel would be broken. We apprehend that a mathematician would be puzzled how to explain the ſtability of an arch cut out of a ſolid and uniform maſs of rock. His theory conſiders the mutual thruſts of the arch ſtones as in the direction of the tangents to the arch. Why ſo? becauſe he ſuppoſes that all his poliſhed joints are perpendicular to thoſe tangents. But in the preſent caſe he has no exiſting joints; and there ſeems to be nothing to direct his imagination in the aſſumption of joints, which, however, are abſolutely neceſſary for employing his theory, becauſe, without a ſuppoſition of this kind, there ſeems no conceiving any mutual abutment of the arch ſtones. Aſk a common, but intelligent, maſon what notion he forms of ſuch an arch? We apprehend that he will conſider it as no arch, but as a lintel, which may be broken like a wooden lintel, and which reſiſts entirely by its coheſion. He will not readily conceive that, by cutting the under ſide of a ſtone lintel into an arched form, and thus taking away more than half of its ſubſtance, he has changed its nature of a lintel, or given it any additional ſtrength. Nor would there be any change made in the way in which ſuch a maſs of ſtone would reſiſt being broken down, if nothing were done but forming the under ſide into an arch. If the lintel be ſo laid on the piers that it can be broken without its parts puſhing the piers aſide (which will be the caſe if it lies on the piers with horizontal joints), it will break like any other lintel; but if the joints are directed downwards, and converging to a point within the arch, the broken ſtone (ſuppoſe it broken at the crown by an overload in that part) cannot be preſſed down without forcing the piers outwards. Now, in this mode of acting, the mind cannot trace any thing of the ſtatical equilibrium that we have proceeded on in the foregoing theory. The two parts of the broken lintel ſeem to puſh the piers aſide in the ſame manner that two rafters puſh outwards the walls of a houſe, when their feet are not held together by a tye-beam. If the piers cannot be puſhed aſide (as when the arch abuts on two ſolid rocks), nothing can preſs down the crown which does not cruſh the ſtone.

This concluſion will be ſtrictly true if the arch is of ſuch a form that a ſtraight line drawn from the crown to the pier lies wholly within the ſolid maſonry. Thus if the vault conſiſt of two ſtraight ſtones, as in fig. 1. or if it conſiſt of ſeveral ſtones, as in fig. 14. diſpoſed in two ſtraight lines, no weight laid on the crown can deſtroy it in any other way but by cruſhing it to powder.

29 When it is to be called into the aid of the builder.

But when ſtraight lines cannot be drawn from the overloaded part to the firm abutments through the ſolid maſonry, and when the coheſion of the parts is not able to withſtand the tranſverſe ſtrains, we muſt call the principles of equilibrium to our aid; and, in order to employ them with ſafety, we muſt conſider how they are modified by the excitement of the cohering forces.

The coheſion of the ſtones with each other by cement or otherwiſe, has, in almoſt every ſituation, a bad effect. It enables an overload at the crown to break the arch near the haunches, cauſing thoſe parts to riſe, and then to ſpread outwards, juſt as a Manſarde or Kirb roof would do if the truſs-beam which connects the heads of the lower rafters were ſawn through. This can be prevented only by loading that part more than is requiſite for equilibrium. It would be prudent to do this to a certain degree, becauſe it is by this coheſion that the crown always becomes the weakeſt part of the arch, and ſuffers more by any occaſional load.

We expect that it will be ſaid in anſwer to all this, that the coheſion given by the ſtrongeſt cement that we can employ, nay the coheſion of the ſtone itſelf, is a mere nothing in compariſon with the enormous thruſts that are in a ſtate of continual exertion in the different parts of an arch. This is very true; but there is another force which produces the ſame effect, and which increaſes nearly in the proportion that thoſe thruſts increaſe, becauſe it ariſes from them. This is the friction of the ſtones on each other. In dry freeſtone this friction conſiderably exceeds one-half of the mutual preſſure. The reflecting reader will ſee that this produces the ſame effect, in the caſe under conſideration, that coheſion would do; for while the arch is in the act of failing, the mutual preſſure of the arch ſtones is acting with full force, and thus produces a friction more than adequate to all the effects we have been ſpeaking of.

30
Proceſs of the breaking of an arch.

When theſe circumſtances are conſidered, we imagine that it will appear that an arch, when expoſed to a great overload on the crown (or indeed on any part), divides, of itſelf, into a number of parts, each of which contains as many arch ſtones as can be pierced (ſo to ſpeak) by one ſtraight line, and that it may then be conſidered as nearly in the ſame ſituation with a polygonal arch of long ſtones butting on each other like ſo many beams in a Norman roof (ſee Roof, nº 49), but without their braces and ties. It tends to break at all thoſe angles; and it is not ſufficiently reſiſted there, becauſe the materials with which the flanks are filled up have ſo little coheſion, that the angle feels no load except what is immediately above it; whereas it ſhould be immediately loaded with all the weight which is diffuſed over the adjoining ſide of the polygon. This will be the caſe, even though the curvelineal arch be perfectly equilibrated. We recollect ſome circumſtances in the failure of a conſiderable arch, which may be worth mentioning. It had been built of an exceedingly ſoft and friable ſtone, and the arch ſtones were too ſhort. About a fortnight before it fell, chips were obſerved to be dropping off from the joints of the archſtones about ten feet on each ſide of the middle, and alſo from another place on one ſide of the arch, about twenty feet from its middle. The maſons in the neighbourhood prognoſticated its ſpeedy downfal, and ſaid that it would ſeparate in thoſe places where the chips were breaking off. At length it fell; but it firſt ſplit in the middle, and about 15 or 16 feet on each ſide, and alſo at the very ſpringing of the arch. Immediately before the fall a ſhivering or crackling noiſe was heard, and a great many chips dropped down from the middle between the two places from whence they had dropped a fortnight before. The joints opened above at thoſe new places above two inches, and in the middle of the arch the joints opened below, and in about five minutes after this the whole came down. Even this movement was plainly diſtinguiſhable into two parts. The crown ſunk a little, and the haunches roſe very ſenſibly, and in this ſtate it hung for about half a minute. The arch ſtones of the crown were hanging by their upper corners. When theſe ſplintered off, the whole fell down.

We apprehend that the procedure of nature was ſomewhat in this manner. Straight lines can be drawn within the archſtones from A (fig. 15.) to B and D, and from thoſe points to C and E. Each of the portions ED, DA, AB, BC, reſiſt as if they were of one ſtone, compoſing a polygonal vault EDABC. When this is overloaded at A, A can deſcend in no other way than by puſhing the angles B and D outwards, cauſing the portions BC, DE, to turn round C and E. This motion muſt raiſe the points B and D, and cauſe the arch ſtones to preſs on each other at their *inner* joints *b* and *d*. This produced the copious ſplintering at thoſe joints immediately preceding the total downfal. The ſplintering which happened a fortnight before aroſe from this circumſtance, that the lines AB and AD, along which the preſſure of the overload was propagated, were tangents to the ſoffit of the arch in the points F, H, and G, and therefore the ſtrain lay all on thoſe corners of the arch ſtones, and ſplintered a little from off them till the whole took a firmer bed. The ſubſequent phenomena are evident conſequences of this diſtribution and modification of preſſure, and can hardly be explained in any other way; at leaſt not on the theoretical principles already ſet forth: for in this bridge the loads at B and D were very conſiderably greater than what the equilibrium required; and we think that the firſt obſerved ſplintering at H, F, and G, was moſt inſtructive, ſhowing that there was an extraordinary preſſure at the inner joints in thoſe places, which cannot be explained by the uſual theory.

Not ſatisfied with this ſingle obſervation, after this way of explaining it occurred to us, and not being able to find any ſimilar fact on record, the writer of this article got ſome ſmall models of arches executed in chalk, and ſubjected them to many trials, in hopes of collecting ſome general laws of the internal workings of arches which finally produce their downfal. He had the pleaſure of obſerving the above mentioned circumſtances take place very regularly and uniformly, when he overloaded the models at A. The arch always broke at ſome place B conſiderably beyond another point F, where the firſt chipping had been obſerved. This is a method of trial that deſerves the attention both of the ſpeculatiſt and the practitioner.

If theſe reflections are any thing like a juſt account of the procedure of nature in the failure of an arch, it is evident that the ingenious mathematical theory of equilibrated arches is of little value to the engineer. We ventured to ſay as much already, and we reſted a good deal on the authority of Sir Chriſtopher Wren. He was a good mathematician, and delighted in the application of this ſcience to the arts. He was a celebrated architect; and his reports on the various works committed to his charge, ſhow that he was in the continual habit of making this application. Several ſpecimens remain of his own methods of applying them. The roof of the theatre of Oxford, the roof of the cupola of St. Paul's, and in particular the mould on which he turned the inner dome of that cathedral, are proofs of his having ſtudied this theory moſt attentively. He flouriſhed at the very time that it occupied the attention of the greateſt mechanicians of Europe; but there is nothing to be found among his papers which ſhows that he had paid much regard to it. On the contrary, when he has occaſion to deliver his opinion for the inſtruction of others, and to explain to the Dean and Chapter of Weſtminſter his operations in repairing that collegiate church, this great architect conſiders an arch juſt as a ſenſible and ſagacious maſon would do, and very much in the way that we have juſt now been treating it: (See *Account of the Family of Wren*, p. 356, &c.) Supported therefore by ſuch authority, we would recommend this way of conſidering an arch to the ſtudy of the mathematician; and we would deſire the experienced maſon to think of the moſt efficacious methods for reſiſting this tendency of arches to riſe in the flanks. Unfortunately there ſeems to be no preciſe principle to point out the place where this tendency is moſt remarkable.

We are therefore highly pleaſed with the ingenious contrivance of Mr. Mylne, the architect of Blackfriars Bridge in London, by which he determines this point with preciſion, by making it impoſſible for the overloaded arch to ſpring in any other place. Having thus confined the failure to a particular ſpot, he with equal art oppoſes a reſiſtance which he believes to be ſufficient; and the preſent condition of that noble bridge, which does not in any place ſhow the ſmalleſt change of ſhape, proves that he was not miſtaken. Looking on this work as the firſt, or at leaſt the ſecond, ſpecimen of maſonic ingenuity that is to be ſeen in the world, we imagine that our readers will be pleaſed with a particular account of its moſt remarkable circumſtances.

31 Conſtruction of Blackfriars Bridge. Plate III.

The ſpan *k a* (fig. 16.) of the middle arch is 100 feet, and its height OV is 40, and the thickneſs KV of the crown is ſix feet ſeven inches. Its form is nearly elliptical; the part AVZ being an arch of a circle whoſe centre is C, and radius 56 feet, and the two lateral portions A *k* B and Z *a* E being arches deſcribed with a radius of 35 feet nearly. The thickneſs of the pier at *a b* is 19 feet. The thickneſs of the arch increaſes from the crown V to Y, where it is eight or nine feet. All the arch ſtones have their joints directed to the centres of their curvature. The joints are all joggled, having a cubic foot of hard ſtone let half way into each. By this contrivance the joints cannot ſlide, nor can any weight laid on the crown ever break the arch in that part, if the piers do not yield; for a ſtraight line from the middle of KV to the middle of the joint YI is contained within the ſolid maſonry, and does not even come near the inner joints of the arch ſtones. Therefore the whole reſiſts like one ſtone, and can be broken only by cruſhing it. The joint at Z is very nearly perpendicular to a line YF drawn to the outer edge of the foundation of the pier. By this it was intended to take off all tendency of the preſſure on the joint *d* Z to overſet the pier; for if we ſuppoſe, according to the theory of equilibration, that this preſſure is neceſſarily exerted perpendicularly to the joint, its direction paſſes through the fulcrum at F, round which it is thought that the pier muſt turn in the act of overſetting. This precaution was adopted, in order to make the arch quite independent of the adjoining arches; ſo that although any of them ſhould fall, this arch ſhould run no riſk.

Still farther to ſecure the independence of the arch, the following conſtruction was practiſed to unite it into one maſs, which ſhould riſe all together. All below the line *a b* is built of large blocks of Portland ſtone, dovetailed with ſound oak. Four places in each courſe are interrupted by equal blocks of a hard ſtone called *Kentiſh rag*, ſunk half way in each courſe. Theſe act as joggles, breaking the courſes, and preventing them from ſliding laterally.

The portion *a* Y of the arch is joggled like the upper part. The interior part is filled up with large blocks of Kentiſh rag, forming a kind of courſed rubble-work, the courſes tending to the centres of the arch. The under corner of each arch ſtone projects over the one below it. By this form it takes faſt hold of the rubble-work behind it. Above this rubble there is conſtructed the inverted arch I *e* G of Portland ſtone. This arch ſhares the preſſure of the two adjoining arches, along with the arch ſtones in Y *a* and in G *b*. Thus all tend together to compreſs and keep down the rubble-work in the heart of this part of the pier. This is a very uſeful precaution; for it often happens, that when the centres of the arches are ſtruck, before the piers are built up to their intended height, the thruſt of the arches ſqueezes the rubble-work horizontally, after the morter has ſet, but before it has dried and acquired its utmoſt hardneſs. Its bond is broken by this motion, and it is ſqueezed up, and never acquires its former firmneſs. This is effectually prevented by the preſſure exerted by the back of the inverted arch.

Above this counter arch is another maſs of courſed rubble, and all is covered by a horizontal courſe of large blocks of Portland ſtone, butting againſt the back of the arch ſtone ZI and its correſponding one in the adjoining arch. This courſe connects the feet of the two arches, preſerves the rubble work from too great compreſſion, and protects it from ſoaking water. This laſt circumſtance is important; for if the water which falls on the road-way is not carried off in pipes, it ſoaks through the gravel or other rubbiſh, reſts on the morter, and keeps it continually wet and ſoft. It cannot eſcape through the joints of good maſonry, and therefore fills up this part like a funnel.

Suppoſing the adjoining arch fallen, and all tumbled off that is not withheld by its ſituation, there will ſtill remain in the pier a maſs of about 3500 tons. The weight of the portion VY is about 2000 tons. The directions of the thruſts RY and YF are ſuch, that it would require a load of 4500 tons on VY to overturn the pier round F. This exceeds VY by 2500 tons; a weight incomparably greater than any that can ever be laid on it.

Such is the ingenious conſtruction of Mr. Mylne. It evidently proceeds on the principles recommended above; principles which have occurred to his experience and ſagacious mind during the courſe of his extenſive practice. We have ſeen attempts by other engineers to withſtand the horizontal thruſts of the arch by means of counter arches inſerted in the ſame manner as here, but extending much farther over the main arch; but they did not appear to be well calculated for producing this effect. A counter arch ſpringing from any point between Y and V has no tendency to hinder that point from riſing by the ſinking of the crown; and ſuch a counter arch will not reſiſt the preciſely horizontal thruſt ſo well as the ſtraight courſe of Mr. Mylne.

32 Origin of the Gothic arches.

The great incorporation of architects who built the cathedrals of Europe departed entirely from the ſtyles of ancient Greece and Rome, and introduced another, in which arcades made the principal part. Not finding in every place quarries from which blocks could be raiſed in abundance of ſufficient ſize for forming the far-projecting corniches of the Greek orders, they relinquiſhed thoſe proportions, and adopted a ſtyle of ornament which required no ſuch projections: and having ſubſtituted arches for the horizontal architrave or lintel, they were now able to erect buildings of vaſt extent with ſpacious openings, and all this with very ſmall pieces of ſtone. The form which had been adopted for a Chriſtian temple occaſioned many interſections of vaultings, and multiplied the arches exceedingly. Conſtant practice gave opportunities of giving every poſſible variety of theſe interſections, and taught the art of balancing arch againſt arch in every variety of ſituation. An art ſo multifarious, and ſo much out of the road

Saliſbury cathedral are not eight inches thick after the octagon is fully formed. It is proper, however, to direct the joints to the axis of the pyramid, and to make the courſing joints perpendicular to the ſlant ſide, becauſe the projecting mouldings which run along the angles are the abutments on which the whole pannel depends. A conſiderable art is neceſſary for ſupporting thoſe pannels or ſides of the octagon which ſpring from the angles of the ſquare tower. This is done by beginning a very narrow pointed arch on the ſquare tower at a great diſtance below the top; ſo that the legs of the arch being very long, a ſtraight line may be drawn from the top of the keyſtone of the arch through the whole arch ſtones of the legs. By this diſpoſition the thruſts ariſing from the weight of theſe four pannels are made to meet on the maſſive maſonry in the middle of the ſides of the tower, at a great diſtance below the ſpringing of the ſpire. This part, being loaded with the great maſs of perpendicular wall, is fully able to withſtand the horizontal thruſt from the legs of thoſe arches. In many ſpires theſe thruſts are ſtill farther reſiſted by iron bars which croſs the tower, and are hooked into pieces of braſs firmly bedded in the maſonry of the ſides.

38
Examples of ſuch conſtruction.

There is much nice balancing of this kind to be obſerved in the highly ornamented open ſpires; ſuch as thoſe of Bruſſels, Mechlin, Antwerp, &c. We have not many of this ſort in Britain. In thoſe of great magnitude, the judicious eye will diſcover that parts, which a common ſpectator would conſider as mere ornaments, are neceſſary for completing the balance of the whole. Tall pinnacles, nay, even pillars carrying entablatures and pinnacles, are to be ſeen ſtanding on the middle of the ſlender leg of an arch. On examination, we find that this is neceſſary, to prevent the arch from ſpringing upwards in that place by the preſſure at the crown. The ſteeple of the cathedral of Mechlin was the moſt elaborate piece of architecture in this taſte in the world, and was really a wonder; but it was not calculated to withſtand a bombardment, which deſtroyed it in 1578.

Such frequent examples of irregular and whimſical buildings of this kind, ſhow that great liberties may be taken with the principle of equilibration without riſk, if we take care to ſecure the baſe from being thruſt outwards. This may always be done by hoops, which can be concealed in the maſonry; whereas, in common arches, theſe ties would be viſible, and would offend the eye.

Plate II.

39
Stability of a dome depends on principles

It is now time to attend to the principle of equilibrium, as it operates in a ſimple circular dome, and to determine the thickneſs of the vaulting when the curve is given, or the curve when the thickneſs is given. Therefore, let B b A (fig. 17.) be the curve which produces the dome by revolving round the vertical axis AD. We ſhall ſuppoſe this curve to be drawn through the middle of all the arch ſtones, and that the courſing or horizontal joints are every where perpendicular to the curve. We ſhall ſuppoſe (as is always the caſe) that the thickneſs KL, HI, &c. of the arch ſtones is very ſmall in compariſon with the dimenſions of the arch. If we conſider any portion HA b of the dome, it is plain that it preſſes on the courſe, of which HL is an arch ſtone, in a direction b C perpendicular to the joint HI, or in the direction of the next ſuperior element $\beta\, b$ of the curve. As we proceed downwards, courſe after courſe, we ſee plainly that this direction muſt change, becauſe the weight of each courſe is ſuperadded to that of the portion above it, to complete the preſſure on the courſe below. Through B draw the vertical line BCG, meeting $\beta\, b$, produced in C. We may take $b\,c$ to preſs the preſſure of all that is above it propagated in this direction to the joint KL. We may alſo ſuppoſe the weight of the courſe HL united in b, and acting on the vertical. Let it be repreſented by b F. If we form the parallelogram b FGC, the diagonal b G will repreſent the direction and intenſity of the whole preſſure on the joint KL. Thus it appears that this preſſure is continually changing its direction, and that the line, which will always coincide with it, muſt be a curve concave downward. If this be preciſely the curve of the dome, it will be an equilibrated vaulting; but ſo far from being the ſtrongeſt form, it is the weakeſt, and it is the limit to an infinity of others, which are all ſtronger than it. This will appear evident, if we ſuppoſe that b G does not coincide with the curve A b B, but paſſes without it. As we ſuppoſe the arch ſtones to be exceedingly thin from inſide to outſide, it is plain that this dome cannot ſtand, and that the weight of the upper part will preſs it down, and ſpring the vaulting outwards at the joint KL. But let us ſuppoſe, on the other hand, that b G falls within the curvelineal element b B. This evidently tends to puſh the arch ſtone inward, toward the axis, and would cauſe it to ſlide in, ſince the joints are ſuppoſed perfectly ſmooth and ſlipping. But ſince this takes place equally in every ſtone of this courſe, they muſt all abut on each other in the vertical joints, ſqueezing them firmly together. Therefore, reſolving the thruſt b G into two, one of which is perpendicular to the joint KL, and the other parallel to it, we ſee that this laſt thruſt is withſtood by the vertical joints all around, and there remains only the thruſt in the direction of the curve. Such a dome muſt therefore be firmer than an equilibrated dome, and cannot be ſo eaſily broken by overloading the upper part. When the curve is concave upwards, as in the lower part of the figure, the line b C always falls below b B, and the point C below B. When the curve is concave downwards, as in the upper part of the figure, 'b C' paſſes above, or without b B. The curvature may be ſo abrupt, that even b' G′ ſhall paſs without 'b B′, and the point G′ is above B′. It is alſo evident that the force which thus binds the ſtones of a horizontal courſe together, by puſhing them towards the axis, will be greater in flat domes than in thoſe that are more convex; that it will be ſtill greater in a cone; and greater ſtill in a curve whoſe convexity is turned inwards: for in this laſt caſe the line b G will deviate moſt remarkably from the curve. Such a dome will ſtand (having poliſhed joints) if the curve ſprings from the baſe with any elevation, however ſmall; nay, ſince the friction of two pieces of ſtone is not leſs than half of their mutual preſſure, ſuch a dome will ſtand, although the tangent to the curve at the bottom ſhould be horizontal, provided that the horizontal thruſt be double the weight of the dome, which may eaſily be the caſe if it do not riſe high.

40
Different from that of a common arch.

Thus we ſee that the ſtability of a dome depends on very different principles from that of a common arch, and is in general much greater. It differs alſo in another

41 Excellency of the dome of St Paul's.

ther very important circumſtance, viz. that it may be open in the middle: for the uppermoſt courſe, by tending equally in every part to ſlide in toward the axis, preſſes all together in the vertical joints, and acts on the next courſe like the key-ſtone of a common arch. Therefore an arch of equilibration, which is the weakeſt of all, may be open in the middle, and carry at top another building, ſuch as a lanthern, if its weight do not exceed that of the circular ſegment of the dome that is omitted. A greater load than this would indeed break the dome, by cauſing it to ſpring up in ſome of the lower courſes; but this load may be increaſed if the curve is flatter than the curve of equilibration: and any load whatever, which will not cruſh the ſtones to powder, may be ſet on a truncate cone, or on a dome formed by a curve that is convex toward the axis; provided always that the foundation be effectually prevented from flying out, either by a hoop, or by a ſufficient maſs of ſolid pier on which it is ſet. We have mentioned the many failures which happened to the dome of St Sophia in Conſtantinople. We imagine that the thruſt of the great dome, bending the eaſtern arch outward as ſoon as the pier began to yield, deſtroyed the half dome which was leaning on it, and thus, almoſt in an inſtant, took away the eaſtern abutment. We think that this might have been prevented, without any change in the injudicious plan, if the dome had been hooped with iron, as was practiſed by Michael Angelo in the vaſtly more ponderous dome of St Peter's at Rome, and by Sir Chriſtopher Wren in the cone and the inner dome of St Paul's at London. The weight of the latter conſiderably exceeds 3000 tons, and they occaſion a horizontal thruſt which is nearly half this quantity, the elevation of the cone being about 60°. This being diſtributed round the circumference, occaſions a ſtrain on the hoop $= \frac{7}{2 \times 22}$ of the thruſt, or nearly 238 tons. A ſquare inch of the worſt iron, if well forged, will carry 25 tons with perfect ſafety; therefore a hoop of 7 inches broad and $1\frac{1}{2}$ inches thick will completely ſecure this circle from burſting outwards. It is, however, much more completely ſecured; for beſides a hoop at the baſe of very nearly theſe dimenſions, there are hoops in different courſes of the cone which bind it into one maſs, and cauſe it to preſs on the piers in a direction exactly vertical. The only thruſts which the piers ſuſtain are thoſe from the arches of the body of the church and the tranſepts. Theſe are moſt judiciouſly directed to the entering angles of the building, and are there reſiſted with inſuperable force by the whole lengths of the walls, and by four ſolid maſſes of maſonry in the corners. Whoever conſiders with attention and judgment the plan of this cathedral, will ſee that the thruſts of theſe arches, and of the dome, are incomparably better balanced than in St Peter's church at Rome. But to return from this ſort of digreſſion.

42 Theory of the curves proper for domes.

We have ſeen that if b G, the thruſt compounded of the thruſt b C, exerted by all the courſes above HILK, and if the force b F, or the weight of that courſe, be every where coincident with b B, the element of the curve, we ſhall have an equilibrated dome; if it falls within it, we have a dome which will bear a greater load; and if it falls without it, the dome will break at the joint. We muſt endeavour to get analytical expreſſions of theſe conditions. Therefore draw the ordinates $b \delta b''$, BDB'', C d C''. Let the tangents at b and b'' meet the axis in M, and make MO, MP, each equal to $b\,c$, and complete the parallelogram MONP, and draw OQ perpendicular to the axis, and produce b F, cutting the ordinates in E and e. It is plain that MN is to MO as the weight of the arch HAb to the thruſt $b\,c$ which it exerts on the joint KL (this thruſt being propagated through the courſe HILK); and that MQ, or its equal $b\,e$, or $\delta\,d$, may repreſent the weight of the half AH.

Let AD be called x, and DB be called y. Then $b\,e = \dot{x}$, and $e\,\mathrm{C} = \dot{y}$ (becauſe $b\,c$ is in the direction of the element $\beta\,b$). It is alſo plain, that if we make $\dot{y}$ conſtant, BC is the ſecond fluxion of x, or BC $= \ddot{x}$, and $b\,e$ and BE may be conſidered as equal, and taken indiſcriminately for $\dot{x}$. We have alſo $b\,\mathrm{C} = \sqrt{\dot{x}^2 + \dot{y}^2}$. Let d be the depth or thickneſs HI of the arch ſtones. Then $d\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the trapezium HL: and ſince the circumference of each courſe increaſes in the proportion of the radius y, $d\,y\sqrt{\dot{x}^2 + \dot{y}^2}$ will expreſs the whole courſe. If $\int$ be taken to repreſent the ſum or aggregate of the quantities annexed to it, the formula will be analogous to the fluent of a fluxion, and $\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}$ will repreſent the whole maſs, and alſo the weight of the vaulting, down to the joint HI. Therefore we have this proportion $\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2} : d\,y\sqrt{\dot{x}^2 + \dot{y}^2} = b\,e : b\,\mathrm{F}, = b\,e : \mathrm{CG}, = \delta d : \mathrm{CG}, = \dot{x} : \mathrm{CG}$. Therefore $\mathrm{CG} = \frac{d\,y\,\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}$.

If the curvature of the dome be preciſely ſuch as puts it in equilibrium, but without any mutual preſſure in the vertical joints, this value of OG muſt be equal to CB, or to $\ddot{x}$, the point G coinciding with B. This condition will be expreſſed by the equation $\frac{d\,y\,\dot{x}\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \ddot{x}$, or, more conveniently, by $\frac{d\,y\sqrt{\ddot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}}$. But this form gives only a tottering equilibrium, independent of the friction of the joints and the coheſion of the cement. An equilibrium, accompanied by ſome firm ſtability, produced by the mutual preſſure of the vertical joints, may be expreſſed by the formula $\frac{d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} > \frac{\ddot{x}}{\dot{x}}$, or by $\frac{d\,y\sqrt{\dot{x}^2 + \dot{y}^2}}{\int d\,y\sqrt{\dot{x}^2 + \dot{y}^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, where t is ſome variable poſitive quantity, which increaſes when x increaſes.

by giving connection to the upper parts, cauſes the whole to preſs more vertically on the courſe below, and thus diminiſhes the outward thruſt; but it at the ſame time diminiſhes the mutual abutment of the vertical joints, which is a great cauſe of firmneſs in the vaulting. A Gothic dome, of which the upper part is a portion of a ſphere not exceeding 45° from the vertex, and the lower part is concave outwards, will be very ſtrong, and not ungraceful.

43 Dome of St Peter's at Rome.

But the public taſte has long rejected this form, and ſeems rather to ſelect more elevated domes than this portion of a ſphere; becauſe a dome, when ſeen from a ſmall diſtance, always appears flatter than it really is. The dome of St Peter's is nearly an ellipſoid externally, of which the longer axis is perpendicular to the horizon. It is very ingeniouſly conſtructed. It ſprings from the baſe perpendicularly, and is very thick in this part. After riſing about 50 feet, the vaulting ſeparates into two thin vaultings, which gradually ſeparate from each other. Theſe two ſhells are connected together by thin partitions, which are very artificially dovetailed in both, and thus form a covering which is extremely ſtiff, while it is very light. Its great ſtiffneſs was neceſſary for enabling the crown of the dome to carry the elegant ſtone lanthern with ſafety. It is a wonderful performance, and has not its equal in the world; but it is an enormous load in compariſon with the dome of St. Paul's, and this even independent of the difference of ſize. If they were of equal dimenſions, it would be at leaſt five times as heavy, and is not ſo firm by its gravity; but as it is connected in every part by iron bars (lodged in the ſolid maſonry, and well ſecured from the weather by having lead melted all round them), it bids fair to laſt for ages, if the foundations do not fail.

Plate II.

If a circle be deſcribed round a centre placed anywhere in the tranſverſe axis AC (fig. 18. N° 1.) of an ellipſe, ſo as to touch the ellipſe in the extremities B, *b*, of an ordinate, it will touch it internally, and the circular arch B *a b* will be wholly within the elliptical arch BA *b*. Therefore, if an elliptical and a ſpherical vaulting ſpring from the ſame baſe, at the ſame angle with the horizon, the ſpherical vaulting will be within the elliptical, will be flatter and lighter, and therefore the weight of the next courſe below will bear a greater proportion to the thruſt in the direction of the curve; therefore the ſpherical vaulting will have more ſtability. On the contrary, and for ſimilar reaſons, an oblate elliptical vaulting is preferable to a ſpherical vaulting ſpringing with the ſame inclination to the horizon. (Fig. 18. N° 2.)

44 Dimenſions of the beſt form of a dome.

Perſuaded, that what has been ſaid on the ſubject convinces the reader that a vaulting perfectly equilibrated throughout is by no means the beſt form, provided that the baſe is ſecured from ſeparating, we think it unneceſſary to give the inveſtigation of that form, which has a conſiderable intricacy; and ſhall content ourſelves with merely giving its dimenſions. The thickneſs is ſuppoſed uniform. The numbers in the firſt column of the table expreſs the portion of the axis counted from the vertex, and thoſe of the ſecond column are the lengths of the ordinates.

AD	DB	AD	DB	AD	BD
0,4	100	610,4	1080	2990	1560
3,4	200	744	1140	3442	1600
11,4	300	904	1200	3972	1640
26,6	400	1100	1260	4432	1670
52,4	500	1336	1320	4952	1700
91,4	600	1522	1360	5336	1720
146,8	700	1738	1400	5756	1740
223,4	800	1984	1440	6214	1760
326,6	900	2270	1480	6714	1780
465,4	1000	2602	1520	7260	1800

The curve delineated in fig. 19. is formed according to theſe dimenſions, and appears deſtitute of gracefulneſs; becauſe its curvature changes abruptly at a little diſtance from the vertex, ſo that it has ſome appearance of being made up of different curves pieced together. But if the middle be occupied by a lanthern of equal, or of ſmaller weight, this defect will ceaſe, and the whole will be elegant, nearly reſembling the exterior dome of St Paul's in London.

45 Advantages of dome-vaulting.

It is not a ſmall advantage of dome-vaulting that it is lighter than any that can cover the ſame area. If, moreover, it be ſpherical, it will admit conſiderable varieties of figure, by combining different ſpheres. Thus, a dome may begin from its baſe as a portion of a large hemiſphere, and may be broken off at any horizontal courſe, and then a ſimilar or a greater portion of a ſmaller ſphere may ſpring from this courſe as a baſe. It alſo bears being interſected by cylindrical vaultings in every direction, and the interſections are exact circles, and always have a pleaſing effect. It alſo ſprings moſt gracefully from the heads of ſmall piers, or from the corners of rooms of any polygonal ſhape; and the arches formed by its interſections with the walls are always circular and graceful, forming very handſome ſpandrels in every poſition. For theſe reaſons Sir Chriſtopher Wren employed it in all his vaultings, and he has exhibited many beautiful varieties in the tranſepts and the aiſles of St Paul's, which are highly worthy of the obſervation of architects. Nothing can be more graceful than the vaultings at the ends of the north and ſouth tranſepts, eſpecially as finiſhed off in the fine inſide view publiſhed by Gwynn and Wale.

46 Effects of cement and friction in dome vaulting.

We conclude this article with obſerving, that the connection of the parts, ariſing from cement and from friction, has a great effect on dome-vaulting. In the ſame way as in common arches and cylindrical vaulting, it enables an overload on one place to break the dome in a diſtant place. But the reſiſtance to this effect is much greater in dome-vaulting, becauſe it operates all round the overloaded part. Hence it happens that domes are much leſs ſhattered by partial violence, ſuch as the falling of a bomb or the like. Large holes may be broken in them without much affecting the reſt; but, on the other hand it greatly diminiſhes the ſtrength which ſhould be derived from the mutual preſſure in the vertical joints. Friction prevents the ſliding in of the arch ſtones which produces this mutual preſſure in the vertical joints, except in the very higheſt courſes, and even

there

PLATE II.

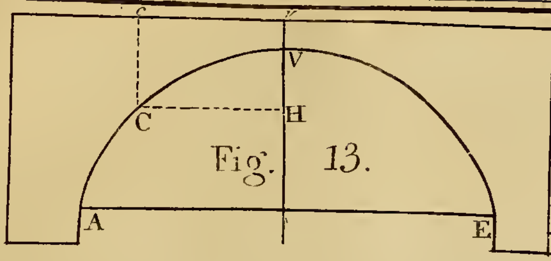


Fig. 13.

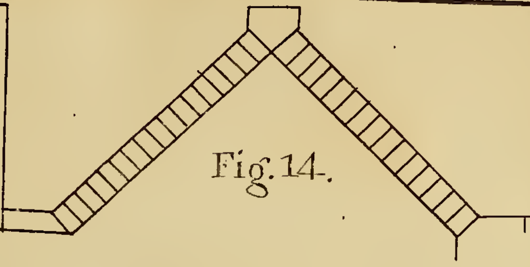


Fig. 14.

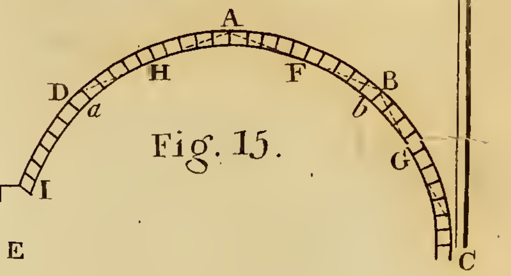


Fig. 15.

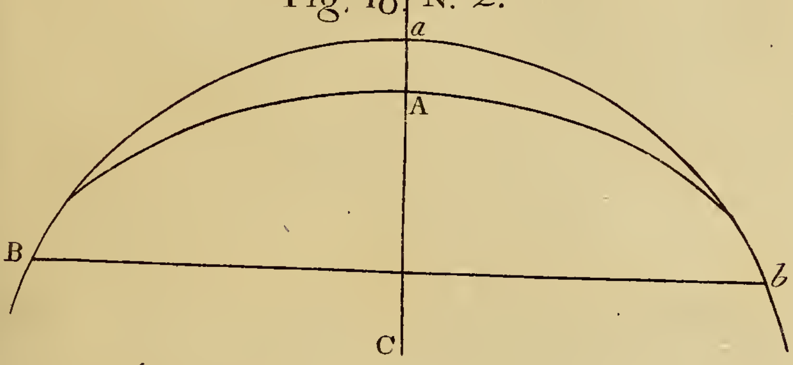


Fig. 18. Nº 2.

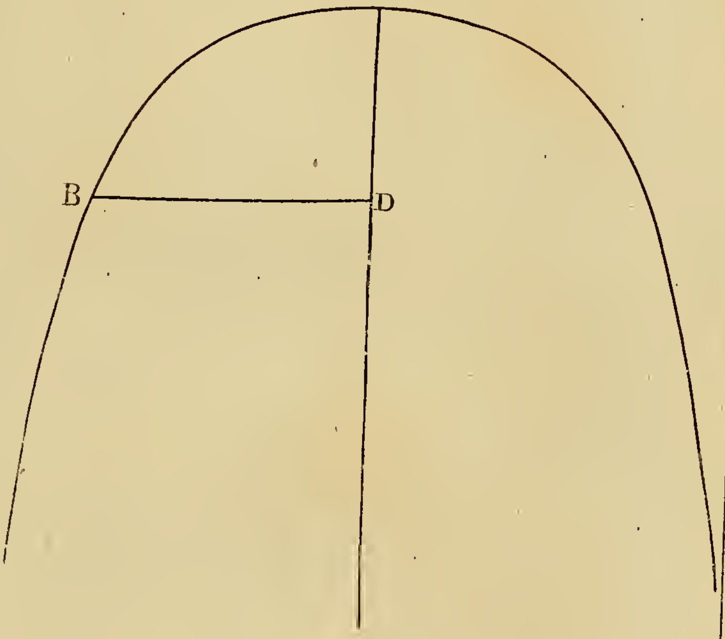


Fig. 19.

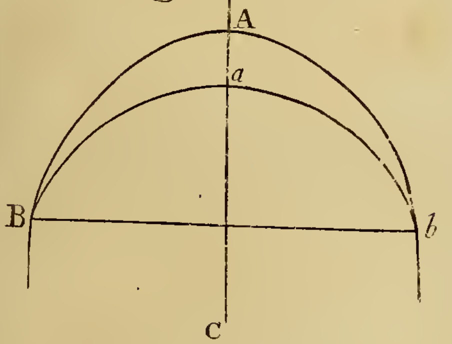


Fig. 18. Nº 1.

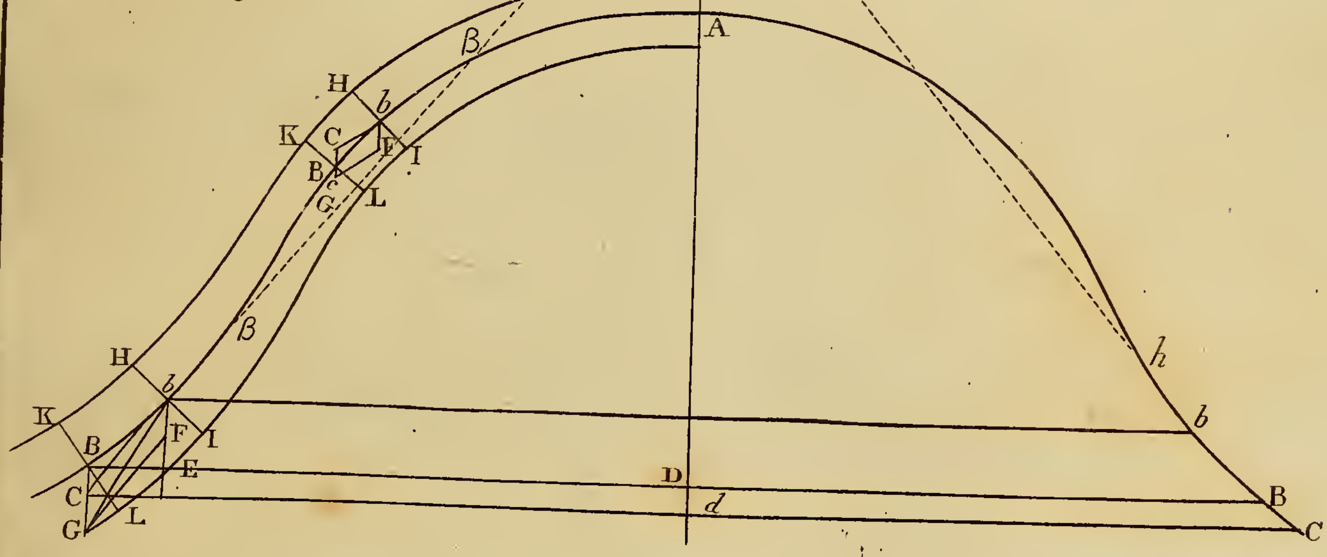


Fig. 17.

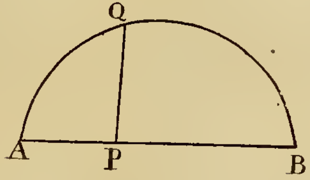


Fig. 2.

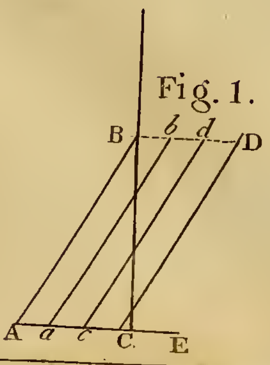


Fig. 1.

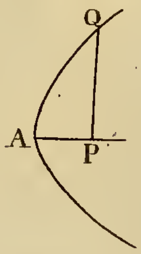


Fig. 4.

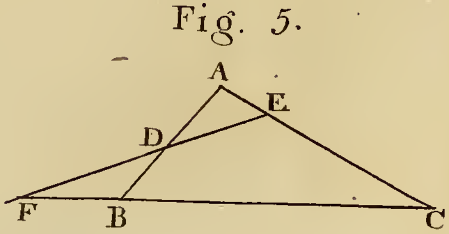


Fig. 5.

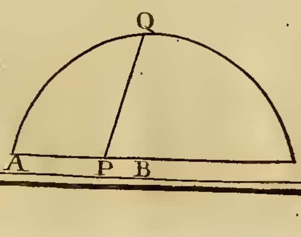


Fig. 3.

J. Bowes sc.

there it greatly diminiſhes it. Theſe cauſes make a great change in the form which gives the greateſt ſtrength: and as their laws of action are but very imperfectly underſtood as yet, it is perhaps impoſſible, in the preſent ſtate of our knowledge, to determine this form with tolerable preciſion. We ſee plainly, however, that it allows a greater deviation from the beſt form than the other kind of vaulting, and domes may be made to riſe perpendicular to the horizon at the baſe, although of no great thickneſs; a thing which muſt not be attempted in a plane arch. The immenſe addition of ſtrength which may be derived from hooping, largely compenſates for all defects; and there is hardly any bounds to the extent to which a very thin dome vaulting may be carried, when it is hooped or framed in the direction of the horizontal courſes. The roof of the Halle du Bled at Paris is but a foot thick, and its diameter is more than 200, yet it appears to have abundant ſtrength. It is, on the whole, a noble ſpecimen of architecture.

47
The iron bridge at Sunderland deſcribed.

We muſt not conclude this article without taking notice of that magnificent and elegant arch which has been erected in caſt iron at Weremouth, near Sunderland, in the county of Durham. The inventor and architect is Rowland Burdon, Eſq; one of the repreſentatives of that county in the preſent Parliament.

This arch is a ſegment of a circle whoſe diameter is about 444 feet. The ſpan or cord of the arch is 236 feet, and its verſed ſine or ſpring is 34 feet. It ſprings at the elevation of 60 feet from the ſurface of the river at low water, ſo that veſſels of 200 or perhaps 300 tons burden may paſs under it in the middle of the ſtream, and even 50 feet on each ſide of it.

The ſweep of the arch conſiſts of a ſeries of frames of caſt iron, which butt on each other, in the ſame manner as the vouſſoirs of a ſtone arch. One of theſe frames or blocks (as we ſhall call them in future) is repreſented in fig. 1. as ſeen in front. It is caſt in one piece; and conſiſts of three pieces or arms BC, BC, BC, the middle one of which is two feet long, the upper being ſomewhat more, and the lower ſomewhat leſs, becauſe their extremities are bounded by the radius drawn from the centre of the arch. Theſe arms are four inches ſquare, and are connected by other pieces KL, of ſuch length that the whole length of the block is five feet in the direction of the radius. Each arm has a flat groove on each ſide, which is expreſſed by the darker ſhading, three inches broad and three-fourths of an inch deep. A ſection of this block, through the middle of KL, is repreſented by the light-ſhaded part BBB, in which the grooves are more diſtinctly perceived. Theſe grooves are intended for receiving flat bars of malleable iron, which are employed for connecting the different blocks with each other. Fig. 2. repreſents two blocks united in this manner. For this purpoſe each arm has two ſquare bolt-holes. The ends of the arms being nicely trimmed off, ſo that the three ends butt equally cloſe on the ends of the next block; and the bars of hammered iron being alſo nicely fitted to their grooves, ſo as to fill them completely, and have their bolt-holes exactly correſponding to thoſe in the blocks, they are put together in ſuch a manner that the joints or meetings of the malleable bars may fall on the middle between the bolt-holes in the arms. Flat headed bolts of wrought iron are then put through, and keys or forelocks are driven through the bolt-tails, and thus all is firmly wedged together, binding each arm between two bars of wrought iron. Theſe bars are of ſuch length as to connect ſeveral blocks.

Plate IV.

In this manner a ſeries of about 125 blocks are joined together, ſo as to form the preciſe curve that is intended. This ſeries may be called a rib, and it ſtands in a vertical plane. The arch conſiſts of ſix of theſe ribs, diſtant from each other five feet. Theſe ribs are connected together ſo as form an arch of 32 feet in breadth, in the following manner.

Fig. 3. repreſents one of the bridles or croſs pieces which connect the different ribs, as it appears when viewed from below. It is a hollow pipe of caſt iron, four inches in diameter, and has at each end two projecting ſhoulders, pierced with a bolt hole near their extremities, ſo that the diſtance between the bolt-holes in the ſhoulders of one end is equal to the diſtance between the holes in the arms of the blocks, or the holes in the wrought iron bars. In the middle of the upper and of the underſide of each end may be obſerved a ſquare prominence, more lightly ſhaded than the reſt. Theſe projections alſo advance a little beyond the flat of the ſhoulders, forming between them a ſhallow notch, about an inch deep, which receives the iron of the arms, where they butt on each other, and thus gives an additional firmneſs to the joint. The manner in which the arms are thus graſped by theſe notches in the bridles is more diſtinctly ſeen in fig. 2. at the letter H in the middle of the upper rail.

The rib having been all trimmed and put together, ſo as to form the exact curve, the bolts are all taken out, and the horizontal bridles are then ſet on in their places, and the bolts are again put in and made faſt by the forelocks. The bolts now paſs through the ſhoulders of the bridles, through the wrought iron bars, and through the caſt iron arm that is between them, and the forelocks bind all faſt together. The manner in which this connection is completed is diſtinctly ſeen in fig. 2. which ſhows in perſpective a double block in front, and a ſingle block behind it. The butting joints of the two front blocks are at the letters E, E, E; the holes in the ſhoulders of the horizontal croſs pieces are at H.

48
Its conſtruction ſimple and judicious,

This conſtruction is beautifully ſimple and very judicious. A vaſt addition of ſtrength and of ſtiffneſs is procured by lodging the wrought iron bars in grooves formed in the caſt iron rails; and for this purpoſe it is of great importance to make the wrought iron bars fill the grooves completely, and even to be ſo tight as to require the force of the forelocks to draw them home to the bottom of the grooves. There can be no doubt but that this arch is able to withſtand an enormous preſſure, as long as the abutments from which it ſprings do not yield. Of this there is hardly any riſk, becauſe they are maſſes of rock, faced with about four or five yards (in ſome places only) of ſolid block maſonry. The mutual thruſts of the frames are all in the direction of the rails, ſo that no part bears any tranſverſe ſtrain. We can hardly conceive any force that can overcome the ſtrength of thoſe arms by preſſure or cruſhing them. The manner in which the frames are connected into one rib, effectually ſecures the butting joints from ſlipping; and the accuracy with which the whole can be executed, whoſe exertions have been more or leſs influenced by the ſtate of civilization in which they lived. It would ſeem, however, if we may judge by thoſe various efforts, that little has been effected by mere human ingenuity; ſince we ſee that recourſe has been had, almoſt univerſally, to nature, the great and legitimate ſource of beauty; and that ornament has been attained by the imitation of objects, to which ſhe has given a determinate and characteriſtic form.

“ Where the materials employed are themſelves poſſeſſed of variety and elegance, the attainment of this object requires little or no alteration of their natural forms. Thus cups are made of ſhells, of cocoa nuts, or of oſtrich eggs; the character and beauty of which depend upon the natural form of the materials: and in the caſe of the bottles uſed by the Roman Catholic pilgrims an example occurs of an utenſil, in which the natural form has undergone little or no variation, ſince it conſiſts of the hard outward ſkin of a gourd, of the ſame ſhape in which it grew upon the plant (A). This laſt claſs of forms has been introduced, by imitation, into works compoſed of ſhapeleſs materials. Thus we have ſilver cups in the form of thoſe made of ſhells, and fruit-diſhes of ſtone ware in the form of baſkets.

“ As ſtone is not naturally poſſeſſed of any peculiar ſhape, and as the uſeful object propoſed, by ſtructures formed of it, may be accompliſhed in various ways, very great latitude is left to the invention of the artiſt. We ſee, accordingly, that in every country where much refinement has been introduced, great pains have been beſtowed in ornamenting ſtone buildings with figures repreſenting various natural objects; whilſt the building itſelf has been executed in imitation of a ſtructure, compoſed of materials which naturally poſſeſs a determinate and characteriſtic form. Such was the method followed by the architects of ancient Greece, who conſtructed temples, and other public edifices, in imitation of a ruſtic fabric, compoſed of ſquare beams, ſupported upon round poſts or ſtems of trees, and who derived the numerous ornaments of that beautiful ſtyle from circumſtances which would naturally take place in ſuch a ſtructure.

“ A faint and diſtant reſemblance, however, of the original, has generally been found to anſwer all the end propoſed by the imitation; a reſemblance, which may ſometimes be traced in the general diſtribution of the edifice, ſometimes in its minute parts, and not unfrequently in both.

“ But the forms of nature thus introduced have been greatly modified by thoſe of maſonry. For though ſtone is by nature ſhapeleſs, yet, in the courſe of practice, many peculiar forms have been long eſtabliſhed, and currently employed, in working it; ſuch as ſtraight lines, plain ſurfaces, ſquare angles, and various mouldings uſed to ſoften the effect of abrupt terminations: all of which, originating in motives of mechanical convenience, and of ſimple ornament, had, in very early times, been appropriated to maſonry, and conſidered as eſſential in every finiſhed work of ſtone; ſo that, when the imitation of nature was introduced, theſe maſonic forms ſtill maintained their ground, and, being blended with the forms of nature, the two claſſes reciprocally modified each other.

“ This combination of art with nature, of which we ſee the moſt perfect example in the Corinthian capital, produces what are called architectonic forms, in which the variety of nature, being ſubjected to the regularity of art, the work acquires that peculiar character which, in a natural object, we conſider as offenſive, under the name of *formality*; but which, in architecture, we admire as a beauty, under the name of *ſymmetry*: thus, we reprobate the formality of an avenue, and praiſe the ſymmetry of a colonnade.

“ Such is the nature of architectonic imitation; a device which probably originated in accident, but to which architecture is indebted for its higheſt attainments.”

As the ſtone edifices of ancient Greece were conſtructed in imitation of a wooden fabric, compoſed of ſquare beams laid at right angles on round poſts or ſtems of trees, Sir James conceives that the Gothic fabrics with pointed arches have been executed in imitation of a ruſtic dwelling, conſtructed in the following manner: Suppoſe a ſet of round poſts driven firmly into the ground in two oppoſite rows, the interval between the neighbouring poſts in the ſame row being equal to that between the rows, and each poſt being raiſed above the ground to a height equal to three of thoſe intervals: then a ſet of long and flexible rods of willow being applied to each poſt, let them be thruſt into the ground at its baſe, and bound to it by two tyings, one near the ground, and another at two-thirds of its height; the rods being left looſe from this laſt point upwards, and free to be moved in any direction. Let three rods be connected with each outſide corner poſt, and five with each of the others, and let their poſition be ſuch as to cover the inſide of the poſt, ſo that when ſeen from between the rows the lower part of each poſt ſhall be concealed from the view, and preſent the appearance of a bundle of rods (fig 1.)

Plate V.

Things being thus diſpoſed, the ſkeleton of a thatched roof may be formed by means of the looſe ends of the rods. A rod from one of the poſts being ſo bent as to meet a ſimilar one from the poſt immediately oppoſite to it, in the middle of the ſpace between them, let the two rods be made to croſs each other, and let them be bound together at their croſſing (fig. 2.), and we ſhall have the exact form of the Gothic arch. The ſame being done with each pair of oppoſite poſts, and a ſet of pointed arches being formed, let them be connected together by means of a ſtraight pole laid upon the forks of the croſſing rods, and bound to each of them, as in fig. 3: then let a looſe rod be brought from each of any two contiguous poſts in the ſame row, ſo as to form a pointed arch, ſimilar to that juſt deſcribed, and nearly of the ſame height. This being done with every two contiguous poſts (fig. 4.), and a new ſet of pointed arches being thus produced, ſtanding oppoſite to

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(A) “ Even in this caſe, however, the natural form undergoes a certain degree of modification, by the device employed to produce the neck of the bottle. The fruit, while ſmall and tender, is ſurrounded with a ſtring, which remaining during its growth, prevents the part, thus bound, from ſwelling with the reſt.”

to each other in pairs, let each pair be bound by a horizontal pole lying on the oppoſite forks, and croſſing the longitudinal pole deſcribed above.

“ Two of the rods of each corner poſt, and three of thoſe of each of the others, being thus diſpoſed of, we have one of each corner poſt and two of each middle poſt ſtill to employ, which is done as follows: A pair of theſe unoccupied rods being brought from any two poſts which ſtand diagonally to each other, and made to meet in the middle, not as in the firſt caſe croſſing in an angle, but ſide by ſide, forming a ſemicircle, and joined together after the manner of a hoop; and the ſame being done with every pair of diagonal poſts (fig. 5.), the whole rods will have been employed.

“ In this manner a frame would be conſtructed fit to ſupport thatch or other covering; and ſuch a one has probably been often uſed. It would ſeem, however, that, for the ſake of ſtrength, the number of rods has been increaſed in each cluſter, by the introduction, between every two of them, of an additional rod, which riſing with them to the roof, ſtill continues its middle poſition, as they ſpread aſunder, and meets the horizontal pole at an intermediate point. This is ſhown in fig. 6. which is drawn with its covering of thatch; and, from the imitation of a dwelling ſo conſtructed, we may eaſily trace the three leading characteriſtics of Gothic architecture, the pointed arch, the cluſtered column, and the branching roof, as exhibited in fig. 7.”

Upon the ſame principles Sir James Hall, with much ingenuity, accounts for the peculiar forms of the Gothic door, the Gothic window, and the pointed ſpire: but it is not our intention to ſuperſede the neceſſity of having recourſe to his memoir, but to excite the deſire of our readers to peruſe as well that paper as a larger work which he promiſes on the ſame ſubject, and in which we doubt not but they will find both entertainment and inſtruction. We ſhall conclude this article, therefore, with an experimental proof of the juſtneſs of his hypotheſis.

In the greater part of our late attempts at Gothic architecture, it is allowed by every man of taſte that we have failed. The failure is to be accounted for by the buildings having been conſtructed upon no conſiſtent principle, applicable to every part of them, but upon a ſervile copying of ancient edifices, of which the ſtructure was little underſtood by the copiers. Sir James Hall, however, by applying his theory to practice, has conſtructed a building in this ſtyle, which has far ſurpaſſed, he ſays, his own expectation, and has certainly gained the approbation of every man of taſte and ſcience by whom we have had occaſion to hear it mentioned. “ A ſet of poſts of aſh, about three inches in diameter, were placed in two rows, four feet aſunder, and at the interval of four feet in the rows; then a number of ſlender and tapering willow rods, ten feet in length, were applied to the poſts, and, in the manner which we have deſcribed, formed into a frame, which being covered with thatch, produced a very ſubſtantial roof, under which a perſon can walk with eaſe.

“ This little ſtructure exhibits, in miniature, all the characteriſtic features of the Gothic ſtyle. It is in the form of a croſs, with a nave, a choir, and a north and ſouth tranſept. The thatch, being ſo diſpoſed on the frame as not to hide the rods of which it is compoſed, they repreſent accurately the pointed and ſemicircular arches, and all the other peculiarities of a groined roof.”

ARCTUS, a name given by the Greeks to two conſtellations of the northern hemiſphere, by the Latins called *Ursa Major* and *Minor*, and by us the *Greater* and *Leſſer Bear*.

ARGYLE, a townſhip in Waſhington county, New-York, on the E. bank of Hudſon River, containing 2341 inhabitants, incluſive of 14 ſlaves. In the ſtate cenſus of 1796, there appears to be 404 electors.—*Morse.*

Argyle, a townſhip in Shelburne county, Nova-Scotia, ſettled by Acadians and Scotch.—*ib.*

ARIES *Kill*, a ſmall creek which runs northerly into Mohawk River, 2½ miles W. from Schoharie River, in New-York.—*ib.*

Binary ARITHMETIC. See *Binary Arithmetic*, Encycl.

Duodecimal Arithmetic, is that which proceeds from 12 to 12, or by a continual ſubdiviſion according to 12. This is greatly uſed by moſt artificers in calculating the quantity of their work; as bricklayers, carpenters, painters, tilers, &c.

Harmonical Arithmetic, is ſo much of the doctrine of numbers as relates to the making the compariſons, reductions, &c. of muſical intervals.

Arithmetic of infinites, is the method of ſumming up a ſeries of numbers, of which the number of terms is infinite. This method was firſt invented by Dr. Wallis, as appears by his treatiſe on that ſubject; where he ſhows its uſes in geometry, in finding the areas of ſuperficies, the contents of ſolids, &c. But the method of fluxions, which is a kind of univerſal arithmetic of infinites, performs all theſe more eaſily, as well as a great many other things, which the former will not reach.

Logiſtical Arithmetic, a name ſometimes employed for the arithmetic of ſexageſimal fractions, uſed in aſtronomical computations. Shakerly, in his *Tabulæ Britannicæ*, has a table of logarithms adapted to ſexageſimal fractions, which he calls *logiſtical logarithms*; and the expeditious arithmetic, obtained by means of them, he calls *logiſtical arithmetic*. The term *logiſtical arithmetic*, however, or *logiſtics*, has been uſed by Vieta and others for the rules of computations in algebra.

Political Arithmetic. See *Political Arithmetic*, Encycl.

Sexageſimal Arithmetic. See Arithmetic *(Hiſt.)* Encycl.

Tetractic Arithmetic, is that in which only the four characters, 0, 1, 2, 3, are uſed. A treatiſe of this kind of arithmetic is extant by Erhard or Echard Weigel. But both this and binary arithmetic are little better than curioſities, eſpecially with regard to practice; as all numbers are much more compendiouſly and conveniently expreſſed by the common decuple ſcale.

Univerſal Arithmetic, is the name given by Newton to the ſcience of algebra; of which he left at Cambridge an excellent treatiſe, being the text-book drawn up for the uſe of his lectures, while he was profeſſor of mathematics in that univerſity.

ARITHMETICAL complement, of a logarithm, is what the logarithm wants of 10·00000, &c. and the eaſieſt way to find it is, beginning at the left

GOTHIC ARCHITECTURE.

PLATE V

Fig. 1.

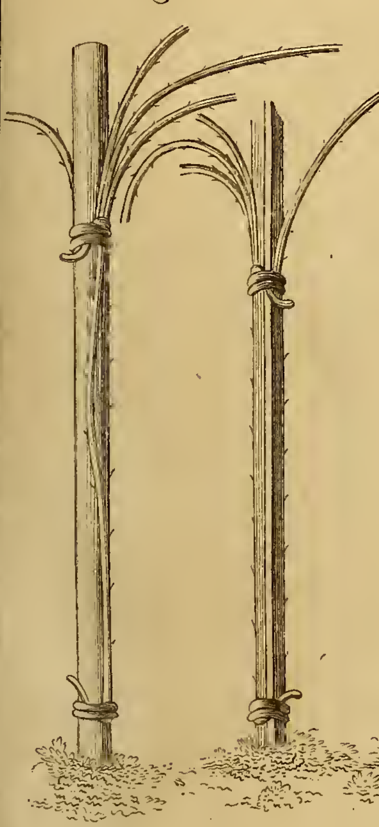


Fig. 2.

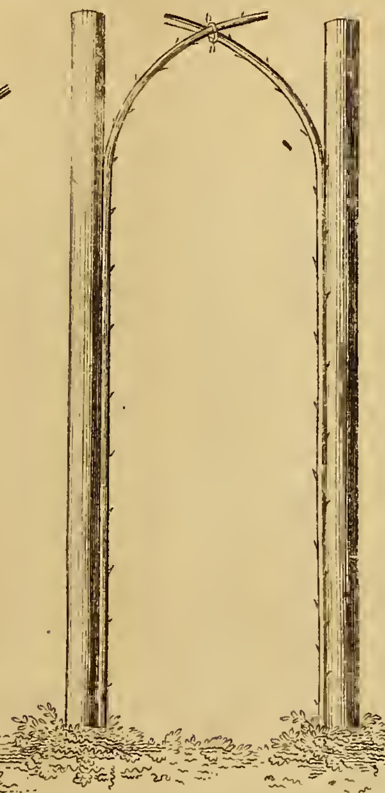


Fig. 3.

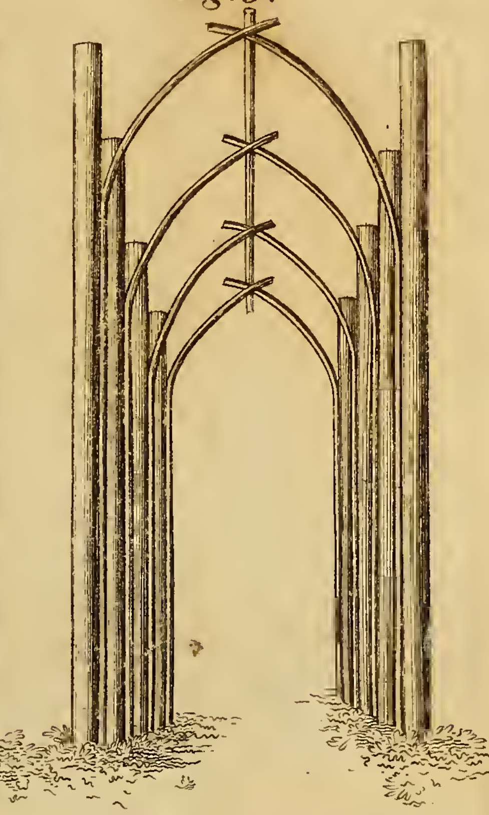


Fig. 4.

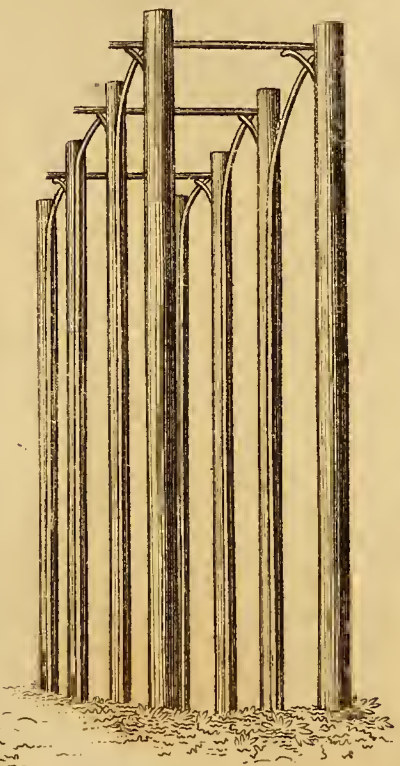


Fig. 6.

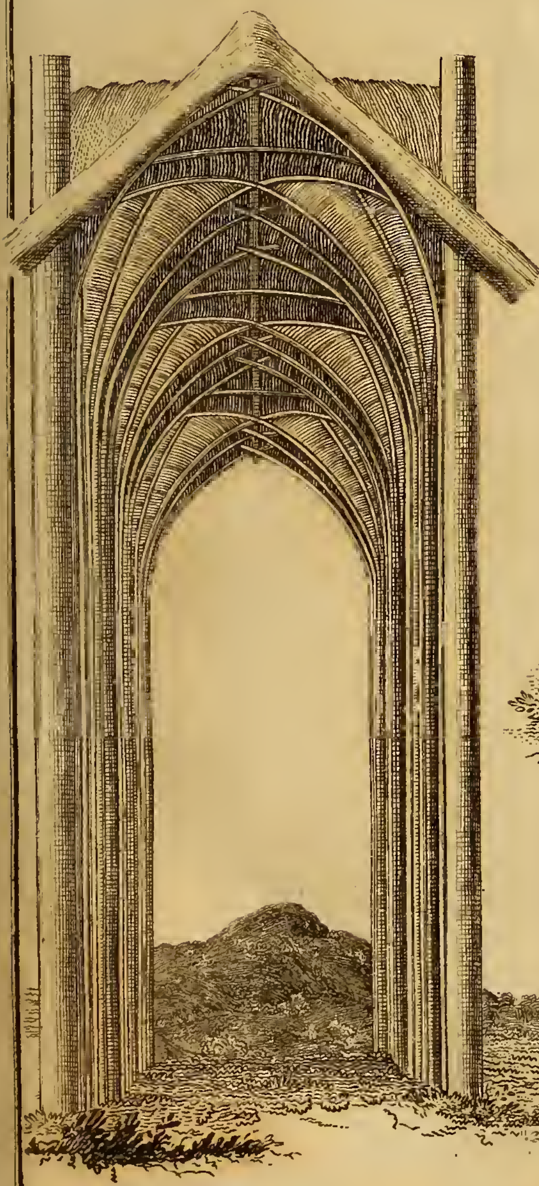


Fig. 5.

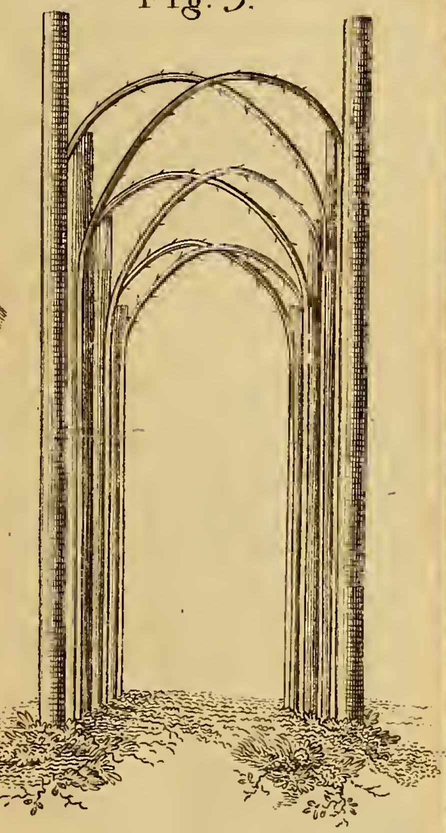
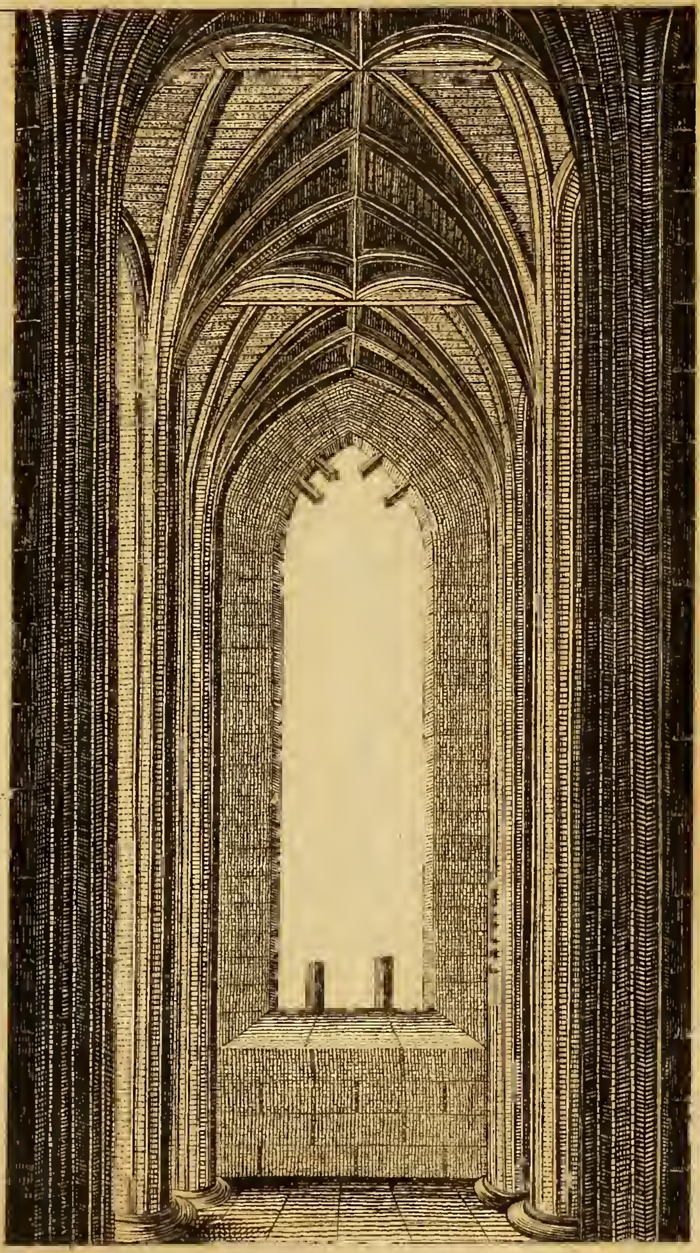


Fig. 7.



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left hand, to ſubtract every figure from 9, and the laſt from 10.

ARLINGTON, a townſhip in Bennington county, Vermont, 12 miles N. from Bennington. It has 991 inhabitants.—*Morse*.

ARRACIFFE, a port town of Brazil, in the captainſhip of Pernambaco; eſteemed the ſtrongeſt in all Brazil. The port conſiſts of a ſuburb, in which are ſome large houſes, and repoſitories for ſtores; and is built upon a narrow paſſage, with a caſtle to defend the entrance. Notwithſtanding which, James Lancaſter entered the harbour in 1595, with 7 Engliſh veſſels, and made himſelf maſter of the town and caſtle, where he continued a month, and carried off immenſe plunder; but ſince that time, the Portugueſe have rendered it almoſt inacceſſible to enemies. Lat. 8. 20. S. long. 36. 10. W.—*ib.*

ARRAYAL De Porate, a town in Brazil, ſituated on the W. ſide of Para River, below the junction of its two great branches.—*ib.*

ARROWSIKE, an iſland in the diſtrict of Maine, parted from Parker's Iſland by a ſmall ſtrait. It is within the limits of George-Town, and contains nearly $\frac{1}{3}$ of its inhabitants, and has a church. It contains about 20,000 acres of land, including a large quantity of ſalt marſh.—*ib.*

ARSACIDES, *the Iſlands of the*, the name given by M. de Surville, in 1769, to Solomon's Iſlands, on account of the barbarous character of their inhabitants, particularly at Port Praſlin. Theſe iſlands were viſited by Mr. Shortland in 1788, and by him called New-Georgia.—*ib.*

ARTEDI (John), was born in the year 1705, in the province of Angermania, in Sweden. From nature he inherited an ardent paſſion for all branches of natural hiſtory, but he excelled moſt in that branch of it which is termed *ichthyology*. In 1724 he went to ſtudy at the univerſity of Upſal, where ſome years afterwards he gained the friendſhip of the immortal Linnæus, who narrates the principal events of his life in the following animated terms.

"In 1728 (ſays Linnæus) I came from Lund to Upſal. I wiſhed to devote myſelf to medicine. I inquired who, at that univerſity, excelled moſt for his knowledge: every one named Artedi. I was impatient to ſee him. I found him pale, and in great diſtreſs for the loſs of his father, with his thin hair neglected. He reſembled the portrait of Ray the naturaliſt. His judgment was ripe, his thoughts profound, his manners ſimple, his virtues antique. The converſation turned upon ſtones, plants, animals. I was enchanted with his obſervations, equally ingenious and new; for at the very firſt he was not afraid to communicate them to me with the utmoſt frankneſs. I deſired his friendſhip, he aſked mine. From that moment we formed a friendſhip; which we cultivated with the greateſt ardour for ſeven months at Upſal. I was his beſt friend, and I never had any who was more dear to me. How ſweet was that intimacy! With what pleaſure did we ſee it increaſe from day to day! The difference, even of our characters, was uſeful to us. His mind was more ſevere, more attentive; he obſerved more ſlowly, and with greater care. A noble emulation animated us. As I deſpaired of ever becoming as well inſtructed in chemiſtry as he, I abandoned it; he alſo ceaſed to ſtudy botany with the ſame ardour, to which I had devoted myſelf in a particular manner. We continued thus to ſtudy different branches of ſcience; and when one of us excelled the other, he acknowledged him for his maſter. We diſputed the palm in ichthyology; but ſoon I was forced to yield, and I abandoned that part of natural hiſtory to him, as well as the amphibia. I ſucceeded better than he in the knowledge of birds and inſects, and he no longer tried to excel in theſe branches. We marched together as equals in lithology, and the hiſtory of quadrupeds. When one of us made an obſervation, he communicated it to the other: ſcarce a day paſſed in which one did not learn from the other ſome new and intereſting particular. Thus emulation excited our induſtry, and mutual aſſiſtance aided our efforts. In ſpite of the diſtance of our lodgings, we ſaw each other every day. At laſt I ſet out for Lapland; he went to London. He bequeathed to me his manuſcripts and his books.

"In 1735 I went to Leyden, where I found Artedi. I recounted my adventures; he communicated his to me. He was not rich, and therefore was unable to be at the expence of taking his degrees in phyſic. I recommended him to Seba, who engaged him to publiſh his work on fiſhes. Artedi went to join him at Amſterdam.

"Scarcely had I finiſhed my *Fundamenta Botanica*. I communicated it to him; he let me ſee his *Philoſophia Ichthyologica*. He propoſed to finiſh as quickly as poſſible the work of Seba, and to put the laſt hand to it. He ſhowed me all his manuſcripts which I had not ſeen: I was preſſed in point of time, and began to be impatient as being detained ſo long. Alas! if I had known this was the laſt time I ſhould ſee him, how ſhould I have prolonged it!

"Some days after, as he returned to ſup with Seba, the night being dark, he fell into the canal. Nobody perceived it, and he periſhed. Thus died, by water, this great ichthyologiſt, who had ever delighted in that element."

Of the works of this eminent naturaliſt there have been two editions, of which the former was publiſhed by Linnæus in 1738, and the latter by Dr. Walbaum of Lubeck, in the years 1788, 1789, and 1792. This edition, which is by much the moſt valuable, is in three volumes 4to; of which the firſt contains the hiſtory of the ſcience of ichthyology, commencing ſeveral years before the Chriſtian era, and coming down to the preſent times. The ſecond preſents to the reader the *Philoſophia Ichthyologica* of Artedi, improved by Walbaum, who was benefited by the writings of Monro, Camper, Kætſeuter and others. Here alſo are added tables containing the ſyſtem of fiſhes by Ray, Dale, Schaeffir, Linnæus, Gowan, Scopola, Klein, and Gronovius. The third volume, which completes the collection of Artedi's works, contains the technical definitions of the ſcience. After the generic and individual characters, come the names and Latin phraſes of Artedi; the ſynonymes of the beſt naturaliſts; the vulgar names in Engliſh, German, Swediſh, Ruſſian, Daniſh, Norwegian, Dutch, and Samoyed; the ſeaſon and the countries where every kind is found, their varieties, their deſcription, and obſervations. The modern diſcoveries, even to our own times, are added; ſo that in ſuppoſition that the motion continues unchanged for ſome time, or that all action ceaſes for ſome time.

This abſtract reaſoning is perfectly agreeable to every phenomenon that we can obſerve with diſtinctneſs. Thus we cannot, or at leaſt we do not, conceive the weight of a body to vary its action during the fall. We conſider this weight as the cauſe of the fall—as the moving force—and we conceive it to act uniformly. And, in fact, a body falling freely, deſcribes ſpaces which are proportional, not to the times, but to the ſquares of the times, and the fall is a motion uniformly accelerated. In like manner, the motion of a body riſing in the air, in oppoſition to gravity, is uniformly retarded.

6
And gives a meaſure of the acquired velocity.

This kind of motion alſo gives us a certain meaſure of the acquired velocity, although there is not, in fact, any ſpace obſerved to be uniformly deſcribed during any time whatever. In this motion we know that the final determination, produced by the accumulated or continued action of the unvaried force, is ſuch that the body would deſcribe uniformly twice the ſpace which it has deſcribed with the accelerated motion.

And it is by this method that we obtain the ſimpleſt meaſure of any moving force, and can compare it with another. If we obſerve that by the action of one force (known to be uniform by the ſpaces being proportional to the ſquares of the times) ten feet have been deſcribed in a ſecond, and that by the uniform action of another force eighty feet are deſcribed in two ſeconds, we know that the laſt force is double of the firſt: for in the ſecond motion, 80 feet were deſcribed in two ſeconds, and therefore 20 feet of this were deſcribed in the firſt ſecond (becauſe the motion is uniformly accelerated); and at the end of a ſecond, the firſt body had a determination by which it would deſcribe 20 feet uniformly in a ſecond; and the ſecond body had acquired a determination by which it would have deſcribed 40 feet uniformly in the next ſecond, had not the moving force continued to act on it, and made it really deſcribe 60 feet with an accelerated motion.

Becauſe halves have the ſame proportions with the units of which they are the halves, it is plain that we may take the ſpaces, deſcribed in equal times with motions uniformly accelerated, as meaſures of the forces which have produced thoſe motions. The velocities generated are, however, the beſt meaſures.

7
Meaſure of the velocity produced by action not uniform.

When the actions of forces are not uniform, it is more difficult to learn what is the meaſure of the velocity produced by their accumulated action. But it can be determined with equal accuracy; that is, we can determine what is the velocity which *would have been produced* by the uniform action of the force during the ſame time, and therefore we obtain a meaſure of the force. Mathematicians are farther able to demonſtrate, that if forces vary their continued action in any manner whatever, the proportion of the ſpaces deſcribed by two bodies in equal times approaches nearer and nearer to the proportion of the ſpaces which they would deſcribe in thoſe times by the uniform action of the forces, as the times themſelves are ſmaller; and therefore whenever we can point out the ultimate ratio of the ſpaces deſcribed in equal times, theſe times being diminiſhed without end, we obtain the ratio of the forces.

Plate VI.

8
Intenſity and direction of deflecting forces.

Motions may be changed, not only in quantity, by acceleration or retardation, but alſo in direction, by deflecting a body from its former direction. When a body, moving uniformly in the direction AB (fig. 1.), has its motion changed in the point B, and, inſtead of deſcribing BC uniformly in the next moment with the former velocity, deſcribes BD uniformly in that moment, it is plain that the motion BD will be the ſame, whether the body had begun to move in A, or in F, or in G, or in B, provided only that its determination to move, or its velocity, be the ſame in all thoſe points. Complete the parallelogram BCDE. It is well known, that if one force act on the body which would make it deſcribe BC, and another which would make it deſcribe BE, the body will deſcribe BD. Hence we learn, that when a body has the motion BC changed into the motion BD, it has been acted on in the point B by a force which would have cauſed a body at reſt in B to deſcribe BE. Thus we can diſcover the intenſity and direction of the tranſverſe force which produces any deflection from the former direction. In general, the force is that which would have produced in a body at reſt that motion BE, which, when compounded with the former motion BC, produces the new motion BD.

Theſe two principles, viz. 1ſt, that forces are proportional to the velocities which they produce in the ſame circumſtances, and, 2d, the compoſition of motion or forces, will ſerve for all the phyſical inveſtigations in aſtronomy. All the celeſtial motions are curvilineal, and therefore are inſtances of continual deflection, and of the continual action of tranſverſe or deflecting forces. We muſt therefore endeavour to obtain a general meaſure of ſuch continual deflecting forces.

9
Meaſure of theſe forces obtained.

Let two bodies A and *a* (fig. 2.) deſcribe in the ſame time the arches AC, *a c* of two circles. They are deflected from the tangents AB, *a b*. Let us ſuppoſe that the direction of the deflecting forces is known to be that of the chords AE, *a e* of theſe circles. Let theſe be called the DEFLECTIVE CHORDS. Draw CB, *c b*, parallel to AE, *a e*, and CD, *c d* parallel to AB, *a b*. Join AC, *a c*, CE, and *c e*. It is plain that the angle BAC is equal to the angle CEA in the alternate ſegment. Therefore ACD is alſo equal to it; and, becauſe the angle CAD is common to the two triangles CAD and EAC, theſe two triangles are ſimilar, and $AD : AC = AC : AE$, and $AD = \frac{AC^2}{AE}$. For ſimilar reaſons $a\,d = \frac{a\,c^2}{a\,e}$. But AD and *a d* are reſpeetively equal to BC and *b c*. Therefore $BC = \frac{AC^2}{AE}$, and $b\,c = \frac{a\,c^2}{a\,e}$. Therefore $BC : b\,c = \frac{AC^2}{AE} : \frac{a\,c^2}{a\,e}$, or $BC : b\,c = AC^2 \times a\,e : a\,c^2 \times AE$. But BC and *b c* being reſpectively equal to AD and *a d*, are equal to the ſpaces through which the deflecting forces would have impelled the bodies from a ſtate of reſt in the time of deſcribing the arches AC, *a c*. Therefore when theſe times are diminiſhed without end, the *ultimate* ratio of AD and *a d* is the ratio of the forces which deflect the bodies in the points A and *a*. But it is evident that the ultimate ratio of AC to *a c* is the ratio of the velocity in the point A to the velocity in the point *a*; becauſe theſe arches are ſuppoſed to be deſcribed in the ſame or equal times. Therefore the deflecting forces, by which bodies are made to deſcribe arches of circles, are to each other as the ſquares of the velocities directly, and as the deflective cords of thoſe circles inverſely. This ratio may be expreſſed ſymbolically thus, $F : f = \frac{V^2}{C} : \frac{v^2}{c}$; or thus, in a proportional equation, $f \doteqdot \frac{v^2}{c}$.

It is eaſy to ſee that in this laſt formula f expreſſes directly the line *b c*, or the ſpace through which the body is actually made to deviate from rectilineal motion in the time of deſcribing the arch *a c*. It is a third proportional to *a e* the deflective chord, and *ac* the arch of the circumference deſcribed in a ſmall moment of time. This is the meaſure afforded immediately by obſervation. We have obſerved the arch AC that is deſcribed, and know the direction and the length of AE from ſome circumſtances of the caſe. The formula which comes to us, when treating this queſtion by the help of fluxions, is $f = \frac{2v^2}{c}$. This is perhaps a more proper expreſſion of the phyſical fact; for it expreſſes twice the line *b c*, or the meaſure of the velocity which the deflecting force would have generated in the body by acting on it during the time of its deſcribing the arch *a c*. But it is indifferent which meaſure we take, provided we always take the ſame meaſure. The firſt mathematicians, however, have committed miſtakes by mixing them.

The planets, however, do not deſcribe circles: but all the curves which can be deſcribed by the action of finite deflecting forces are of ſuch a nature, that we can deſcribe a circle through any point, having the ſame tangent, and the ſame curvature which the planetary curve has in that point, and which therefore ultimately coaleſces with it. This being the caſe, it is plain that the planet, while paſſing through a point of the curve, and deſcribing an indefinitely ſmall arch of it, is in the ſame condition as if deſcribing the coincident arch of the equicurve circle. Hence we obtain this moſt general propoſition, that *the tranſverſe force by which a planet is made to deſcribe any curve, is directly as the ſquare of its velocity, and inverſely as the deflective chord of the equicurve circle.*

Farther: The velocity of a body in any point A (fig. 2.) of the curve, is equal to that which the deflective force in that point would generate in the body by acting uniformly on it along AF, one-fourth part of the deflective cord AE of the equicurve circle. It is the ſame which the body would acquire at F, after a uniformly accelerated motion along AF.

For it is certain that there is ſome length AF, ſuch that the velocity acquired at F is the ſame with the velocity in the point A of the curve. Draw FG parallel to the tangent, and join AG. Make the arch ACI = 2AF. Then, becauſe the ſpace deſcribed with a uniformly accelerated motion is one half of the ſpace which would be uniformly deſcribed with the final velocity, the arch ACI would be uniformly deſcribed with the velocity which the body has at A in the time that AF is deſcribed with the uniformly accelerated motion; and the arch AB will be to the arch AI as the time of deſcribing AB to that of deſcribing AI; that is, as the time of falling through AD to that of falling through AF. But the motion along AF being uniformly accelerated, the ſpaces are as the ſquares of the times. Therefore AD is to AF as the ſquare of the arch AC to the ſquare of the arch AI. But AD is to AF as the ſquare of the chord AC is to the ſquare of the chord AG. Therefore the arch AC is to the chord AC as the arch AI is to the chord AG. But the arch and chord AC are ultimately in the ratio of equality. Therefore the chord AG is equal to the arch AI. Therefore AG is double of AF. But becauſe the triangles FAG and GAE are ſimilar, AF is to AG as AG to AE; and therefore AE is double of AG and quadruple of AF. Therefore the velocity at A in the curve is that which would be produced by the uniform impulſe of the deflecting force along the fourth part of the deflective chord of the equicurve circle.

10 Two uſeful affections of curvilineal motions.

Theſe two affections or properties of curvilineal motions are of the moſt extenſive uſe, and give an eaſier ſolution of moſt queſtions than we obtain by the more uſual methods, and deſerve to be kept in remembrance by ſuch as engage much in the diſcuſſion of queſtions of this kind.

Thus the inveſtigation of the forces which regulate the planetary motions, is reduced to the taſk of diſcovering the velocity of the planet in the different points of its orbit, and the curvature in thoſe points, and the poſition of the deflective chords.

11 Phyſical ſcience of aſtronomy

The phyſical ſcience of aſtronomy muſt conſiſt in the diſcovery of the general laws which can be affirmed with reſpect to the exertion of thoſe forces, whether with reſpect to their direction or the intenſity of their action. If the mechanician can do more than this, and ſhow that every motion that is obſerved is an immediate or remote conſequence of thoſe general laws, he will have completed the ſcience, and explained every appearance.

12 Completed by Newton and

This has accordingly been done by Sir Iſaac Newton and his followers. Sir Iſaac Newton has diſcovered the general laws which regulate the exertions of thoſe forces which produce the planetary motions, by reaſoning from general phenomena which had been obſerved with a certain preciſion before his time; and has alſo ſhown that certain conſiderable deviations from the generality which he ſuppoſed to be perfect were neceſſary conſequences of the very univerſality of the phyſical law, although the phenomenon was not ſo general as was at firſt imagined. He has gone farther, and has pointed out ſome other minute deviations which muſt reſult from the phyſical law, but which the art of obſervation was not then ſufficiently advanced to diſcover in the phenomena. This excited the efforts of men of ſcience to improve the art of aſtronomical obſervation; and not only have the intimations of Newton been verified by modern obſervation, but other deviations have been diſcovered, and, in proceſs of time, have alſo been ſhown to be conſequences of the ſame general law of agency: And, at this preſent day, there is not a ſingle anomaly of the planetary motions which has not been ſhown to be a modification of one general law which regulates the action; and therefore characteriſes the nature of that ſingle force which actuates the whole ſyſtem of the ſun, and his attending planets and comets.

13 His followers.

It was a moſt fortunate circumſtance that the conſtitution of the ſolar ſyſtem was ſuch that the deviations from the general law are not very conſiderable. The caſe might have been far otherwiſe, although the law, or nature of the planetary force, were the ſame, and the ſyſtem had been equally harmonious and beautiful. Had two or three of the planets been vaſtly larger than they are, it would have been extremely difficult to diſcover any laws of their motion ſufficiently general to have led to the ſuſpicion or the diſcovery of the univerſal law of action, or the ſpecific circumſtance in the planetary force which diſtinguiſhes it from all others, and characteriſes its nature. But the three laws of the planetary motions diſcovered by Kepler were ſo nearly true, at leaſt with reſpect to the primary planets, that the deviations could not be obſerved, and they were thought to be exact. It was on the ſuppoſition *that they were exact*, that Newton affirmed that they were only modifications of one law ſtill more general, nay univerſal.

We ſhall follow in order the ſteps of this inveſtigation.

14
The ſteps by which they proceeded.

Sir Iſaac Newton took it for granted, that the ſun and planets conſiſted of matter which reſembled thoſe bodies which we daily handle, at leaſt in reſpect of their mobility; and that the forces which agitate them, conſidered merely as moving forces, but without conſidering or attending to their mode of operation, were to be inferred, both as to their direction and as to their intenſity, from the changes of motion which were aſcribed to their agency. He firſt endeavoured to diſcover the *direction* of that tranſverſe force by which the planets are made to deſcribe curve lines. Kepler's firſt law furniſhed him with ample means for this diſcovery. Kepler had diſcovered, that *the right line joining the ſun and any planet deſcribed areas proportional to the times.* Newton demonſtrated, that if a body was ſo carried round a fixed point ſituated in the plane of its motion, that the right line joining it with that point deſcribed areas proportional to the times, the force which deflected it from an uniform rectilineal motion was continually directed to that fixed point. This makes the 2d propoſition of his immortal work *The Mathematical Principles of Natural Philoſophy*, and it is given in the article ASTRONOMY of the Encyclopædia § 260.

Hence Sir Iſaac Newton inferred, that the primary planets were retained in their orbits by a force continually directed to the ſun; and, becauſe Kepler's law of motion was alſo obſerved by the ſecondary planets in their revolutions round their reſpective primary planets, this inference was extended to them.

15
Centripetal forces.

From the circumſtance that the planetary deflecting forces in the different points of the orbit are always directed toward one point as to a centre, they have been called CENTRIPETAL FORCES.

16
Velocity of a planet in the different points of its orbit.

From this propoſition may be deduced a corollary which eſtabliſhes a general law of the motion of any planet in the different parts of its orbit, namely, that the velocity which a planet has in the different points of its path are inverſely proportional to the perpendiculars drawn from the ſun on the tangents to the orbit in thoſe points reſpectively. For, let AB, *ab* (fig. 3.) be two arches (extremely ſmall), deſcribed in equal times theſe arches muſt be ultimately proportional to the velocities with which they are deſcribed. Let SP, S*p* be perpendicular to the tangents AP, *ap*. The triangles ASB, *a*S*b* are equal, becauſe equal areas are deſcribed by the *radii vectores* SA, S*a*, in equal times: but in equal triangles, the baſes, AB, *ab*, are reciprocally as their heights SP, S*p*, or AB : *ab* = S*p* : SP.

This corollary gives us another expreſſion of the ratio of the centripetal forces in different points A and *a* of a curve. We ſaw by a former propoſition, that the force at A (fig. 2.) is to the force at *a* as $AC^2 \times ae$ to $ac^2 \times AE$, which we may expreſs thus: $F : f = V^2 \times c : v^2 \times C$. If we expreſs the perpendiculars SP, S*p* (in fig. 3.) by the ſymbols P, *p*, we have $V^2 : v^2 = p^2 : P^2$, and therefore $F : f = p^2 \times c : P^2 \times C$. *The centripetal forces in different points of an orbit are in the ratio compounded of the inverſe duplicate ratio of the perpendiculars drawn to the tangents in thoſe points from the centre of forces, and the inverſe ratio of the deflective chords of the equicurve circles.*

17
Law of action of the centripetal force.

We are now in a condition to determine the law of action of the centripetal force by which a planet is retained in its orbit round the ſun, or the relation which ſubſiſts between the intenſity of its action and the diſtance of the planet from the ſun: for we know the elliptical figure of the orbit, and we can draw a tangent to it in any point, and a perpendicular from the ſun to that tangent.

Kepler's ſecond law or obſervation of the planetary motions was, that *each primary planet deſcribed an ellipſe, having the ſun in one focus*. It is eaſy to ſhow, even without any knowledge of the geometrical properties of the ellipſe, what is the proportion of the intenſities of the deflecting force at the aphelion and perihelion (ſee fig. 4.) At thoſe two points of the orbit, the motion of the planet is at right angles to the line joining it with the ſun. Therefore, ſince the areas deſcribed in equal times are equal, the arches deſcribed in equal times muſt be inverſely as the diſtances from the ſun; or the velocities muſt be inverſely as the diſtances from the ſun. But the curvature in the aphelion and perihelion is the ſame; and therefore the diameters of the equicurve circles in thoſe points are equal. But thoſe diameters are, in this particular caſe, what we called the deflective chords. Therefore, calling the aphelion and perihelion diſtances D and *d*, the velocities in the aphelion and perihelion V and *v*, let the common deflective chord be C. Then we have $F : f = V^2 \times C : v^2 \times C$, $= V^2 : v^2$, $= d^2 : D^2$. That is, the forces which deflect the planet in the aphelion and perihelion are inverſely as the ſquares of the diſtances from the ſun. A perſon almoſt ignorant of mathematics may ſee the truth of this by looking into a table of natural verſed ſines. He will obſerve, that the verſed ſine of one degree is quadruple the verſed ſine of half a degree, and ſixteen times the verſed ſine of a quarter of a degree; in ſhort, that the verſed ſines of ſmall arches are in the proportion of the ſquares of the arches. Now ſince the arches deſcribed in equal times are inverſely as the diſtances, their verſed ſines are inverſely as the ſquares of the diſtances. But theſe verſed ſines are the ſpaces through which the centripetal forces at the aphelion and perihelion deflect the planet from the tangent. Therefore, &c.

Thus we have found, that in the aphelion and perihelion the centripetal force acts with an intenſity that is proportional to the ſquares of the diſtances inverſely. As theſe are the extreme ſituations of a planet, and as the proportion of the aphelion and perihelion diſtances are conſiderably different in the different planets, and yet this law of action is obſerved in them all, it is reaſonable to imagine that it holds true, not in thoſe ſituations only, but in every intermediate ſituation. But a conjecture, however probable, is not ſufficient, when we aim at accurate ſcience, and it is neceſſary to examine whether this law of action is really obſerved in every point of the elliptical orbit.

18 Demonſtrated with reſpect to the earth,

For this purpoſe it is neceſſary to mention ſome geometrical properties of the ellipſe. Therefore let ADBE (fig. 4.) be the elliptical orbit of a planet or comet, having the ſun in the focus S. Let AB be the tranſverſe axis, and DE the conjugate axis, and C the centre. Let P be any point of the ellipſe. Draw PS through the focus. Draw the tangent PN, and SN from the focus, perpendicular to PN. Draw PQ perpendicular to PN, meeting the tranſverſe axis in Q. Draw QO parallel to PN, meeting PS in O. Alſo draw QR perpendicular to PS. Biſect PO in T.

It is demonſtrated in the treatiſes of conic ſections, that PO is one half of the chord of the equicurve or oſculating circle drawn through the point P. Therefore PO is one half of the deflective chord of the planetary orbit. It is alſo demonſtrated, that PR is one half of the parameter or *latus rectum* of the tranſverſe axis AB, or that it is the third proportional to AC and DC. Therefore PR or D r is of the ſame conſtant magnitude, in whatever part of the circumference the point P is taken.

It is evident that the triangles NSP, RPQ. and QPO, are all ſimilar, by reaſon of the parallels PN, QO, and the right angles SNP, PRQ, PQO. Therefore we have PR : PQ = PQ : PO. Therefore PR : PO = $PR^2 : PQ^2$, = $SN^2 : SP^2$. Therefore PR × SP^2 = PO × SN^2. But the *latus rectum* L is equal to twice PR, and the deflective chord C is equal to twice PO. Therefore L × SP^2 = C × SN^2. But we have ſeen, that when a curve is deſcribed by means of a centripetal force, ſo that areas are deſcribed proportional to the times, and therefore the velocities are reciprocally proportional to the perpendiculars drawn from the centre of forces to the tangents, the forces are inverſely proportional to C × SN^2. Therefore, in the elliptical motion of the planets, the forces are inverſely proportional to L × SP^2; and ſince L is a conſtant quantity, the centripetal forces are inverſely proportional to SP^2, or to the ſquares of the diſtances from the ſun.

Thus it appears that, with reſpect to any individual planet, the centripetal force which continually deflects it from the tangent to its orbit diminiſhes in the inverſe duplicate ratio of the diſtance from the ſun.

19 Obſerved in the motion of the moon &c.

The ſame thing is obſerved to be very nearly true in the moon's motion round the earth, and in the motion of ſuch ſatellites of Jupiter and Saturn as deſcribe orbits which are ſenſibly elliptical. It is alſo obſerved in the motion of the comets, at leaſt in that which appeared in 1682 and in 1759.

It was therefore very natural for Sir Iſaac Newton to examine whether the like diminution of force obtained in the action of this force on different planets; that is, whether the deflection of the earth from the tangent of its orbit was to the ſimultaneous deflection of Jupiter as the ſquare of Jupiter's diſtance from the ſun to the ſquare of the earth's diſtance. This was very probable, but by no means certain. Its probability is very great indeed, when we know that a comet moves ſo in its orbit that its deflections in equal times are inverſely as the ſquares of its diſtances from the ſun, and that the comet paſſes through the orbits of all the planets; and when at the ſame diſtance from the ſun as any one of them, it ſuffers the ſame deflection with it. Newton therefore calculated the actual ſimultaneous deflections of the different planets, and found them agreeable to this law.

20 And demonſtrated in general terms.

But it was deſirable to obtain a demonſtration of this important propoſition in general terms. This was ſupplied by Kepler's third general obſervation of the motions, viz. that *the ſquares of the periodic times of the different planets were proportional to the cubes of their mean diſtances from the ſun.* The orbits of the planets are ſo nearly circular, that we may ſuppoſe them exactly ſo in the preſent queſtion, without any remarkable error. In this caſe, then, the deflective chords are the diameters of the orbits (for DS is equal to AC), and are proportional to the diſtances, which are their halves. The centripetal forces, being proportional to $\frac{v^2}{c}$, are proportional to $\frac{v^2}{d}$, when d is the radius of the orbit, or the mean diſtance from the ſun. But the velocity in a circular orbit is as the circumference directly, and as the time of a revolution inverſely. Therefore, inſtead of v^2, we may write $\frac{d^2}{t^2}$, and then the forces will be proportional to $\frac{d^2}{t^2\,d}$, or to $\frac{d}{t^2}$; that is, directly as the diſtances, and inverſely as the ſquares of the times of revolution. But, by Kepler's obſervation, t^2 is proportional to d^3. Therefore the centripetal forces are proportional to $\frac{d}{d^3}$, or to $\frac{1}{d^2}$; that is, inverſely as the ſquares of the mean diſtances from the ſun.

But ſince the orbits of the planets are not accurate circles, this determination is but an approximation to the truth, and therefore inſufficient for the foundation of ſo important a propoſition; at any rate, it will not apply to the comets, whoſe orbits are very far from being circular. We muſt obtain a more accurate demonſtration.

Therefore draw SD (fig. 4.) to the extremity of the conjugate axis, and biſect it in t. About S, with the radius SD, deſcribe the circle DFG. Let D d, D δ be equal ſmall arches of the ellipſe and the circle. Join d S, δ S. It is well known that DS is half of the chord of the equicurve circle at D, and therefore D t is one fourth part of it. It has been demonſtrated, that the velocity in any point D of a curve, deſcribed by means of a deflecting force, is that which the force in that point would communicate to it by uniformly impelling it along the fourth part of the deflective chord, that is, along D t. But if a body revolved round S in a circle DFG, its velocity in that circle would be that which the deflecting force would communicate to it by uniformly impelling it along one-fourth of the diameter, that is, along D t. Therefore the planet, if projected in the direction D δ, with the velocity which it has in the point D of the ellipſe, would deſcribe the circle DFG by the action of the centripetal force. Farther, it would deſcribe it in the ſame time that it deſcribes the ellipſe; for becauſe the velocities are equal, the areas

D S d,

DSd, $DS\delta$ are deſcribed in the ſame time. But the baſes Dd, $D\delta$ being equal, theſe areas are as their heights Sn (or CD), and SD (or CA). But becauſe the diameter of the circle is equal to AB, the area of the whole ellipſe is to the area of the circle as CD is to CA; that is, as the area DSd to the area $DS\delta$ deſcribed in the ſame time. Therefore the elliptical and circular areas are ſimilar portions of the ellipſe and circle; and therefore the times of deſcribing them are ſimilar portions of the whole revolutions in the ellipſe and in the circle. Therefore theſe revolutions are performed in equal times.

And thus it follows, that if all the planets and comets were projected, when at their mean diſtances from the ſun, perpendicularly to the *radii vectores*, they would deſcribe circles round the ſun, and the ſquares of their periodic times would be proportional to the cubes of their mean diſtances from the ſun, as Kepler has obſerved; and therefore the centripetal forces would be inverſely as the ſquares of their diſtances from the ſun.

21 All the planets retained in their reſpective orbits by one and the ſame force.

They are not different forces therefore which retain the different planets in their reſpective orbits, but one force, acting by the ſame law upon them all. We may either conceive it as an attractive force, exerted by the ſun, or as a tendency in each planet; nay, nothing hinders us from conceiving it as a force external, both to ſun and planets, impelling them towards the ſun. It may be the impulſe of a ſtream of fluid moving continually toward the ſun. Sir Iſaac Newton did not concern himſelf with this queſtion, but contented himſelf with the diſcovery of the law according to which its action was exerted. The ſteps of this inveſtigation ſhowed him, that a body, projected in any direction whatever, and with any velocity whatever, and ſubjected to the action of a force directed to the ſun, and inverſely proportional to the ſquare of the diſtance from the ſun, will neceſſarily deſcribe a conic ſection, having the ſun in the focus. This will be a parabola, if the velocity of projection be that which the centripetal force in that place would communicate to the body by acting on it uniformly along a line equal to half its diſtance from the ſun. If the velocity be greater than this, the path will be a hyperbola; if the velocity be leſs than this, the path will be an elliptical orbit, in which the body will revolve for ever round the ſun.

The 3d Keplerean law is alſo obſerved in the revolutions of the ſatellites of Jupiter, Saturn, and the lately diſcovered planet; and we muſt infer from it, that they are retained in their orbits round their reſpective primary planets, by forces whoſe intenſity decreaſes according to the ſame law of the diſtances. Alſo the elliptical motion of the moon round the earth, ſhows that the force by which ſhe is retained in her orbit varies in the ſame proportion of the diſtances. But when we compare the motion of a ſatellite of Jupiter with that of one of the ſatellites of the other two planets, we find that the proportion does not hold. We ſhall find, that, at equal diſtances from Jupiter and Saturn, the force toward Jupiter is almoſt thrice as great as the force toward Saturn. We ſhall alſo find that the force toward Jupiter is three hundred times greater than the force which retains the moon in its elliptical orbit round the earth, when acting at the ſame diſtance.

22 The ſatellites of all the planets ſubjected to this ſolar action.

Since a force directed to the ſun, and inverſely as the ſquare of the diſtance, is thus found to pervade all the planetary orbits, it is highly improbable that it will not affect the ſecondary planets alſo. The moon accompanies the earth in its motion round the ſun. It may appear ſufficient for this purpoſe, that the moon be retained in its orbit by a force directed to the earth. Were the moon connected with the earth by a rope or chain, this would be true; for the earth could get no motion without dragging the moon along with it: but it is quite otherwiſe with bodies moving in free ſpace, without any material connections. When a body that is moving uniformly in a ſtraight line is accompanied by another which deſcribes around it areas proportional to the times, the force which continually deflects this ſatellite is always directed to the moving central body. This is eaſily ſeen; for whatever be the mutual action of two bodies, and their relative motions in conſequence of this action, if the ſame velocity be impreſſed at once on both bodies in the ſame direction, their mutual actions and relative motions will be the ſame as they would have been without this common impulſe. Thus every thing is done in a ſhip that is ſailing ſteadily in the ſame manner as if ſhe were at reſt. If therefore the moon be obſerved to deſcribe areas round the earth, which are *preciſely* proportional to the times, while the earth moves in an orbit round the ſun, we muſt infer that the moon receives, in every inſtant, an impulſe the ſame in every reſpect with what the earth receives at the ſame inſtant; or that the moon is acted on by a force parallel to the earth's diſtance from the ſun, and proportional to the ſquare of that diſtance inverſely. Now this is very nearly true of the lunar motions; and we muſt infer that the moon is ſubjected to this ſolar action, or this tendency to the ſun. The ſame muſt be affirmed of the ſatellites of the other planets.

23 How the irregularity of the moon's motion

But a force inverſely proportional to the ſquare of the earth's diſtance from the ſun is not what the univerſality of the law requires: It muſt be inverſely as the ſquare of the moon's diſtance from the ſun: and it muſt not be parallel to the earth's diſtance from the ſun, but muſt be directed toward the ſun; and therefore, in the quadratures, it muſt converge to the earth's *radius vector*. Therefore, ſince a force having the above mentioned conditions will allow the deſcription of areas round the earth exactly proportional to the times, a force acting on the moon, inverſely proportional to the ſquare of her diſtance from the ſun, and directed exactly to the ſun, is incompatible with the accurate elliptical motion round the earth. At new moon, her tendency to the ſun exceeds the earth's tendency to him, and this exceſs will diminiſh her tendency to the earth, and her motion will be leſs incurvated, ſo that ſhe will retire a little from the earth. At full moon, the earth's tendency to the ſun exceeds the moon's tendency to him, and the earth will ſeparate a little from the moon, ſo that the relative orbit will again be leſs incurvated. In the quadratures, the impulſe on the moon is indeed equal to that on the earth, but not parallel, and tends to make the moon approach the earth, and increaſe the curvature of her orbit. In other ſituations of the moon, this want of equality and paralleliſm of the forces acting on the earth and moon, muſt produce other diſturbances of the regular elliptical motion.

PLATE VI.

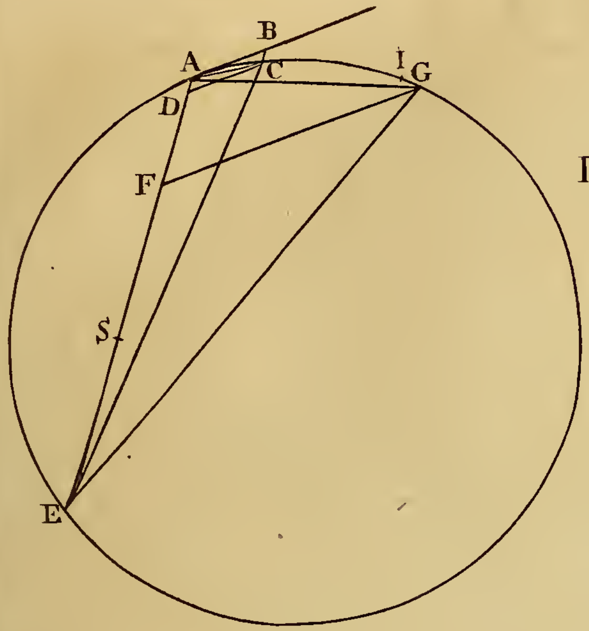


Fig. 2.

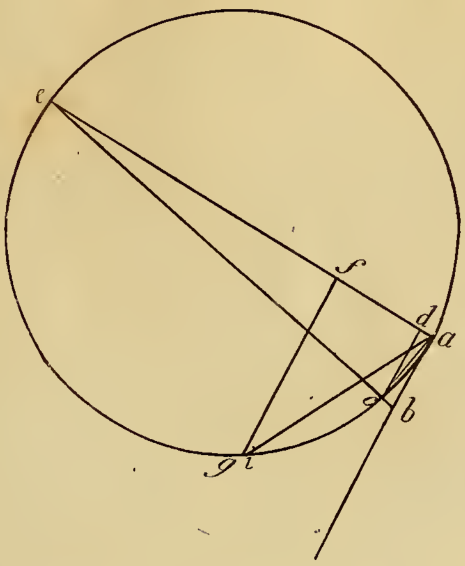


Fig. 5.

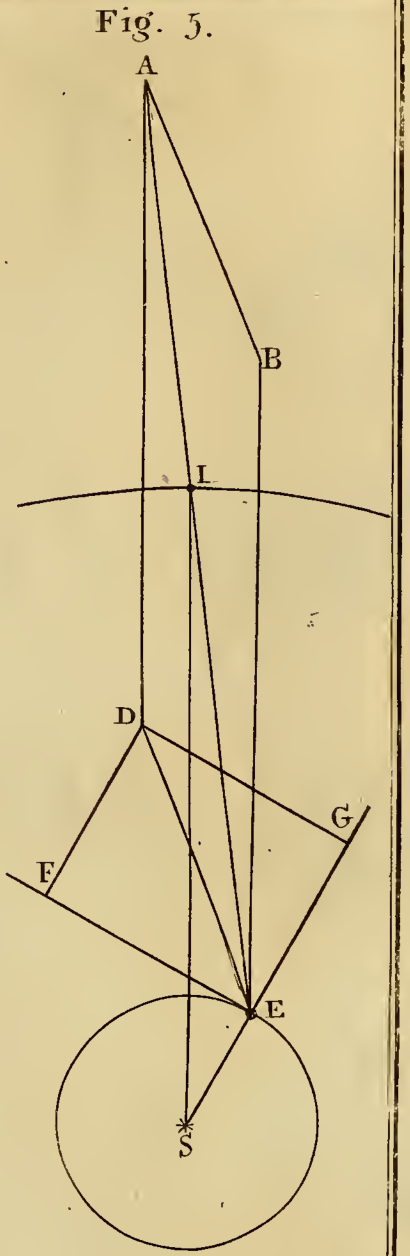


Fig. 1.

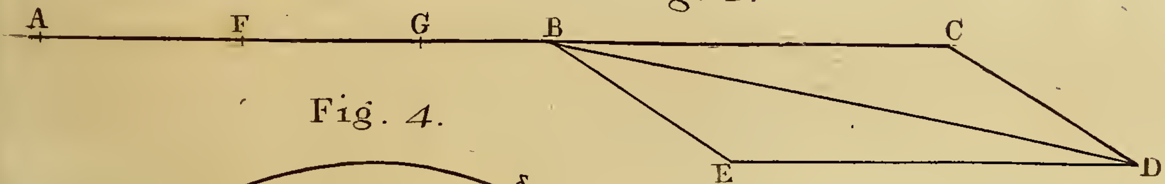


Fig. 4.

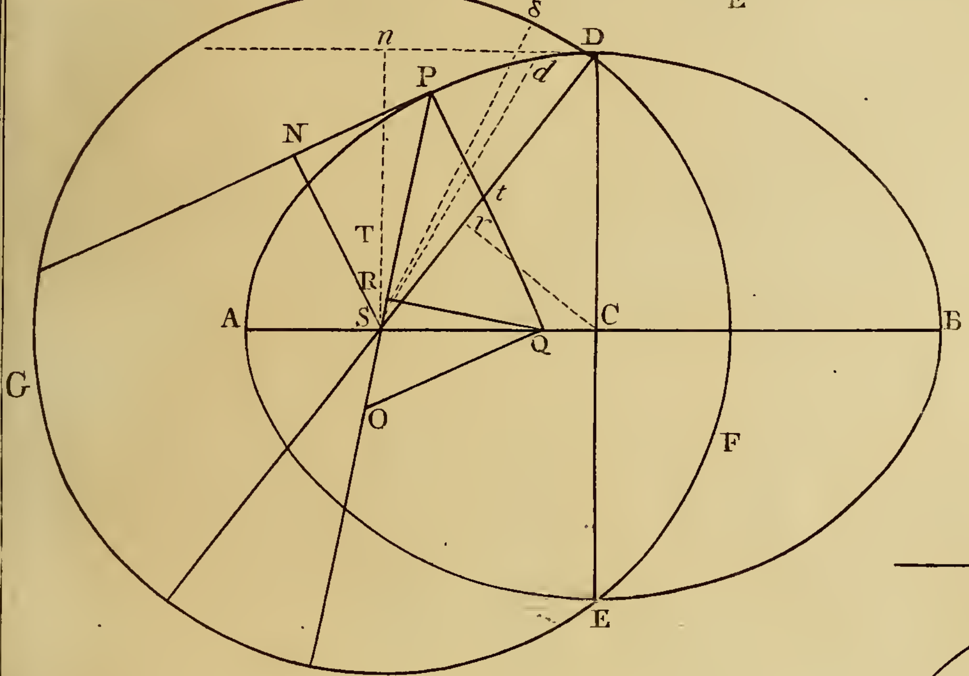


Fig. 3.

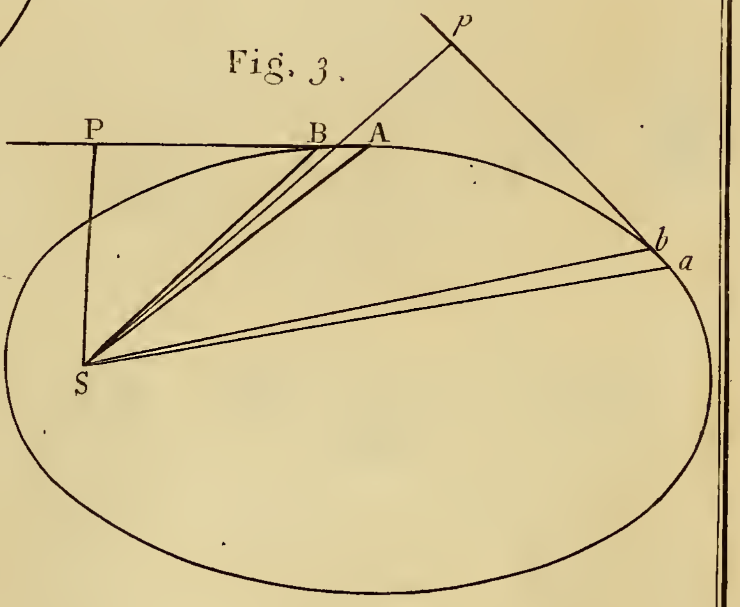
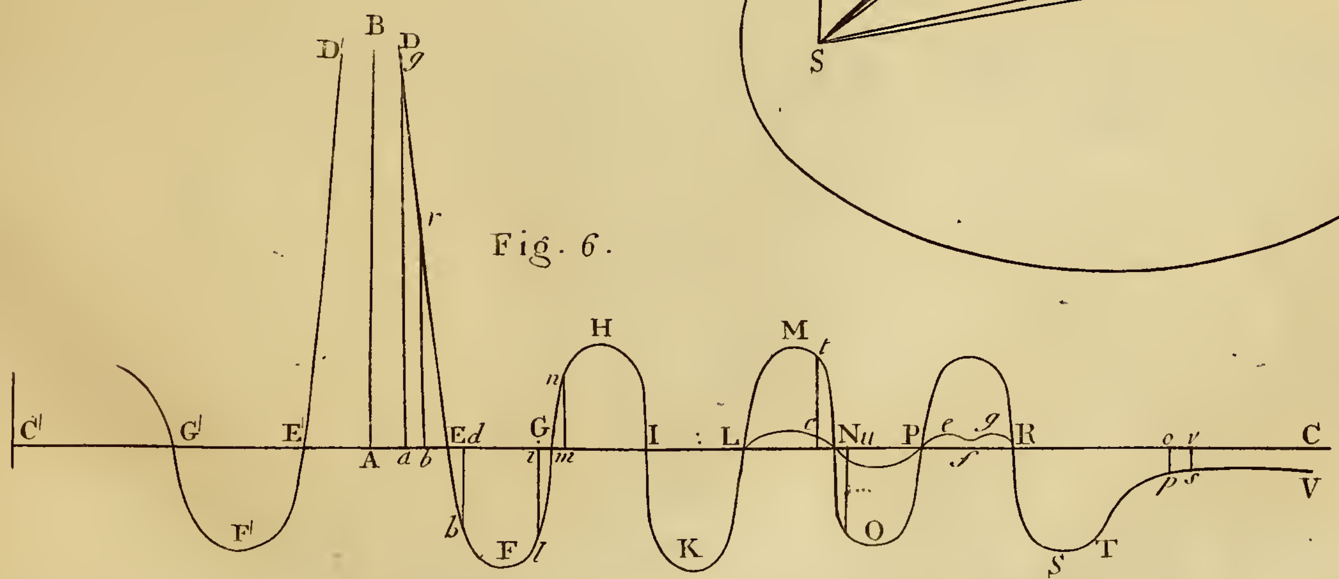


Fig. 6.



J. Bowes. Sc.

Newton ſaw this at once; and, to his great delight, he ſaw that the great deviations from regular motion, which had been diſcovered by Ptolemy and Tycho Brahé called the *Annual Equation*, the *Variation*, and the *Evection*, were ſuch as moſt obviouſly reſulted from the regular influence of the ſun on the moon. The firſt deviation from the regular elliptical motion is occaſioned by the increaſe of the ſun's diſturbing force as the earth approaches the perihelion; and it enlarges the lunar orbit, by diminiſhing the tendency to the earth, and increaſes the periodic time. The ſecond ariſes from the *direction* of the diſturbing force, by which it accelerates the moon's angular motion in the ſecond and fourth quadrants of her orbit, and retards it in the firſt and third. The laſt affects the eccentricity of the orbit, by changing the ratio of the whole or compound tendency of the moon to the earth in her perigee and apogee. 24 May be calculated with preciſion. This ſucceſs incited him to an accurate examination of the conſequences of this influence. It is the boaſt of this diſcovery of the law of the planetary deflections that all its effects may be calculated with the utmoſt preciſion. The part of the moon's deflection toward the ſun, which is neither equal nor parallel to the ſimultaneous deflection of the earth, may be ſeparated from the part which is equal and parallel to it, and it may be called the ſun's diſturbing force. Its proportion to the moon's deflection towards the earth may be accurately aſcertained, and its inclination to the line of the moon's motion in every point of her orbit may be pointed out. This being done, the accumulated effect of this diſturbing force after any given time, however variable, both in direction and intenſity during this time, may be determined by the 39th and other propoſitions of the firſt book of the Mathematical Principles of Natural Philoſophy. And thus may the moon's motion, when ſo diſturbed, be determined and compared with her motion really obſerved.

All this has been done by Sir Iſaac Newton with the moſt aſtoniſhing addreſs and ſagacity, *ſua matheſi facem preferente*, partly in the PRINCIPIA, and partly in his LUNÆ THEORIA. This inveſtigation, whether we conſider the complete originality of the whole proceſs, or the ingenuity of the method, or the ſagacity in ſeeing and clearly diſcriminating the different circumſtances of the queſtion, or the wonderful fertility of reſource, or the new and moſt refined mathematical principles and methods that he employed—muſt ever be conſidered as the moſt brilliant ſpecimen of human invention and reaſoning that ever was exhibited to the world.

In this inveſtigation Newton not only determined the quantity, the period, and the changes of thoſe inequalities, which had been ſo conſiderable and remarkable as to be obſerved by former aſtronomers, and this with an exactneſs far ſurpaſſing what could ever be attained by mere obſervation; but he alſo pointed out ſeveral other periodical inequalities, which were too ſmall, and too much implicated with the reſt, ever to be diſcovered or to be ſeparated from them. We do not ſay that he completed the theory of the lunar motions; but he pointed out the methods of inveſtigation, and he furniſhed all the means of proſecuting it, by giving the world the elements of a new ſpecies of mathematics, without which it would have been in vain to attempt it. Both this new mathematics, and the methods of applying it to ſuch queſtions, have been aſſiduouſly ſtudied and improved by the great mathematicians of this century; and the lunar theory has been carried to ſuch a degree of perfection, that we can compute her place in the heavens for any paſt age without deviating above one minute of a degree from the actual obſervation.

There is one empirical equation of the moon's motion which the compariſon of ancient and modern eclipſes obliges the aſtronomers to employ, without being able to deduce it, like the reſt, *à priori*, from the theory of an univerſal force inverſely proportional to the ſquare of the diſtance. 25 The ſecular equation of the moon's mean diſtance. It has therefore been conſidered as a ſtumbling block in the Newtonian philoſophy. This is what is called *the ſecular equation of the moon's mean motion*. The mean motion is deduced from a compariſon of diſtant obſervations. The time between them, being divided by the number of intervening revolutions, gives the average time of one revolution, or the mean lunar period. When the ancient Chaldean obſervations are compared with thoſe of Hipparchus, we obtain a certain period; when thoſe of Hipparchus are compared with ſome in the 9th century, we obtain a period ſomewhat ſhorter; when the laſt are compared with thoſe of Tycho Brahé, we obtain one ſtill ſhorter; and when Brahé's are compared with thoſe of our day, we obtain the ſhorteſt period of all—and thus the moon's mean motion appears to accelerate continually; and the accelerations appear to be in the duplicate ratio of the times. The acceleration for the century which ended in 1700 is about 9 ſeconds of a degree; that is to ſay, the whole motion of the moon during the 17th century muſt be increaſed 9 ſeconds, in order to obtain its motion during the 18th; and as much muſt be taken from it, or added to the computed longitude, to obtain its motion during the 16th; and the double of this muſt be taken from the motion during the 16th, to obtain its motion during the 15th, &c. Or it will be ſufficient to calculate the moon's mean longitude for any time paſt or to come by the ſecular motion which obtains in the preſent century, and then to add to this longitude the product of 9 ſeconds, multiplied by the ſquare of the number of centuries which intervene. Thus having found the mean longitude for the year 1200, add 9 ſeconds, multiplied by 36, for ſix centuries. By this method we ſhall make our calculation agree with the moſt ancient and all intermediate obſervations. If we neglect this correction, we ſhall differ more than a degree from the Chaldean obſervations of the moon's place in the heavens.

The mathematicians having ſucceeded ſo completely in deducing all the obſerved inequalities of the planetary motions, from the ſingle principle, that the deflecting forces diminiſhed in the inverſe duplicate ratio of the diſtances, were fretted by this exception, the reality of which they could not conteſt. Many opinions were formed about its cauſe. Some have attempted to deduce it from the action of the planets on the moon; others have deduced it from the oblate form of the earth, and the tranſlation of the ocean by the tides; others have ſuppoſed it owing to the reſiſtance of the ether in the celeſtial ſpaces; and others have imagined that the action of the deflecting force requires time for its propagation to a diſtance: But their deductions have been proved unſatisfactory, and have by no means the preciſion and evidence that have been attained in the other queſtions of phyſical aſtronomy. At laſt M. de la Place, of the Royal Academy of Sciences at Paris, has happily ſucceeded, and deduced the ſecular equation of the moon from the Newtonian law of planetary deflection. It is produced in the following manner.

26
Deduced from the Newtonian law of planetary deflection.

Suppoſe the moon revolving round the earth, undiſturbed by any deflection toward the ſun, and that the time of her revolution is exactly aſcertained. Now let the influence of the ſun be added. This diminiſhes her tendency to the earth in oppoſition and conjunction, and increaſes it in the quadratures: but the diminutions exceed the augmentations both in quantity and duration; and the exceſs is equivalent to $\frac{1}{179}$th of her tendency to the earth. Therefore this diminiſhed tendency cannot retain the moon in the ſame orbit; ſhe muſt retire farther from the earth, and deſcribe an orbit which is leſs incurvated by $\frac{1}{179}$th part; and ſhe muſt employ a longer time in a revolution. The period therefore which we obſerve, is not that which would have obtained had the moon been influenced by the earth alone. We ſhould not have known that her natural period was increaſed, had the diſturbing influence of the ſun remained unchanged; but this varies in the inverſe triplicate ratio of the earth's diſtance from the ſun, and is therefore greater in our winter, when the earth is nearer to the ſun. This is the ſource of the annual equation, by which the lunar period in January is made to exceed that in July nearly 24 minutes. The angular velocity of the moon is diminiſhed in general $\frac{1}{179}$, and this numerical coefficient varies in the inverſe ratio of the cube of the earth's diſtance from the ſun. If we expand this inverſe cube of the earth's diſtance into a ſeries arranged according to the ſines and coſines of the earth's mean motion, making the earth's mean diſtance unity, we ſhall find that the ſeries contains a term equal to $\frac{3}{2}$ of the ſquare of the eccentricity of the earth's orbit. Therefore the expreſſion of the diminution of the moon's angular velocity contains a term equal to $\frac{1}{179}$ of this velocity, multiplied by $\frac{3}{2}$ of the ſquare of the earth's eccentricity; or equal to the product of the ſquare of the eccentricity, multiplied by the moon's angular velocity, and divided by 119,33. ($\frac{2}{3}$ of 179). Did this eccentricity remain conſtant, this product would alſo be conſtant, and would ſtill be confounded with the general diminution, making a conſtant part of it: but the eccentricity of the earth's orbit is known to diminiſh, and its diminution is the reſult of the univerſality of the Newtonian law of the planetary deflections. Although this diminution is exceedingly ſmall, its effect on the lunar motion becomes ſenſible by accumulation in the courſe of ages. The eccentricity diminiſhing, the diminution of the moon's angular motion muſt alſo diminiſh, that is, the angular motion muſt increaſe.

During the 18th century, the ſquare of the earth's eccentricity has diminiſhed 0,0000015325, the mean diſtance from the ſun being = 1. This has increaſed the angular motion of the moon in that time 0,00000001285. As this augmentation is gradual, we muſt multiply the angular motion during the century by the half of this quantity, in order to obtain its accumulated effect. This will be found to be 9″ very nearly, which exceeds that deduced, from a moſt careful compariſon of the motion of the laſt two centuries, only by a fraction of a ſecond!

As long as the diminution of the ſquare of the eccentricity of the earth's orbit can be ſuppoſed proportional to the time, this effect will be as the ſquares of the times. When this theory is compared with obſervations, the coincidence is wonderful indeed. The effect on the moon's motion is periodical, as the change of the ſolar eccentricity is, and its period includes millions of years. Its effect on the moon's longitude will amount to ſeveral degrees before the ſecular acceleration change to a retardation.

Thoſe who are not familiar with the diſquiſitions of modern analyſis, may conceive this queſtion in the following manner.

Let the length of a lunar period be computed for the earth's diſtance from the ſun for every day of the year. Add them into one ſum, and divide this by their number, the quotient will be the mean lunar period. This will be found to be greater than the arithmetical medium between the greateſt and the leaſt. Then ſuppoſe the eccentricity of the earth's orbit to be greater, and make the ſame computation. The average period will be found ſtill greater, while the medium between the greateſt and leaſt periods will hardly differ from the former. Something very like this may be obſerved without any calculation, in a caſe very ſimilar. The angular velocity of the ſun is inverſely as the ſquare of his diſtance. Look into the ſolar tables, and the greateſt diurnal motion will be found 3673″, and the leaſt 3433″. The mean of theſe is 3553″, but the medium of the whole is 3548″. Now make a ſimilar obſervation in tables of the motion of the planet Mars, whoſe eccentricity is much greater. We ſhall find that the medium between the greateſt and leaſt exceeds the true medium of all in a much greater proportion.

27
Certainty and utility of this law.

Thus has the patient and aſſiduous cultivation of the Newtonian diſcoveries explained every phenomenon, and enabled us to foreſee changes in them which no examination of the paſt appearances, unaſſiſted by this theory, could have pointed out, and which muſt have exceedingly embarraſſed future aſtronomers. This great but ſimple law of deflection repreſents every phenomenon of the ſyſtem in the moſt minute circumſtances. Far from fearing that future experience may overturn this law, we may reſt aſſured that it will only confirm it more and more; and we may confide in its moſt remote conſequences as if they were actually obſerved.

28
Reciprocal deflection of the earth and moon, and of the ſun and planets,

It is diſcovered by obſervation, that the deflection of the moon to the earth, and of the planets to the ſun, are accompanied by an equal and oppoſite deflection of the earth to the moon, and of the ſun to the planets.

29
Proved by the ebbing and flowing of the ſea,

The tendency of the earth to the moon is plainly indicated by the riſe of the waters of the ocean under the moon, and on the oppoſite ſide of the earth. Sir Iſaac Newton tried what ſhould be the reſult of a tendency of the water to the moon. His inveſtigation of this queſtion was very ſimilar to that in his lunar theory. We may conceive the moon to be one of many millions of particles of a fluid, occupying a globe as big as the lunar orbit. Each will feel a ſimilar diſturbing force, which will diminiſh its tendency to the earth in the neighbourhood of the place of conjunction and oppoſition, and will increaſe it in the neighbourhood of the quadratures. They cannot therefore remain in equilibrio in their ſpherical form; they muſt ſink in the quadratures, and riſe in the conjunction and oppoſition, till their greater height compenſates for the diminiſhed weight of each particle. In like manner, the waters of the ocean muſt ſink on thoſe parts of the earth where the moon is ſeen in the horizon, and muſt riſe in thoſe which have the moon in the zenith or nadir. All theſe effects are not only to be ſeen in general, but they may all be calculated, and the very form pointed out which the ſurface of the ocean muſt aſſume: and thus a tendency of every particle of the ocean to the moon, inverſely proportional to the ſquare of its diſtance from it, gives us a theory of the ebbing and flowing of the ſea. This is delivered in ſufficient detail in the article TIDE of the Encyclopædia, and therefore need not be inſiſted on in this place. The ſame inference muſt be drawn from the preceſſion of the equinoxes produced by the action of the moon on the protuberant matter of our equatoreal regions. See PRECESSION in the Encycl.

30
And by different computations of the ſun's place in the heavens.

But the mutual tendency of the earth and moon is clearly ſeen in a phenomenon that is much more ſimple. If we compute the ſun's place in the heavens, on the ſuppoſition that the earth deſcribes areas proportional to the times, we ſhall find it to agree with obſervation at every new and full moon: But at the firſt quarter the ſun will be obſerved about 9 ſeconds too much advanced to the eaſtward; and at the laſt quarter he will be as much to the weſtward of his calculated place. In all intermediate poſitions, the deviation of the obſerved from the computed place of the ſun will be 9 ſeconds, multiplied by the ſine of the moon's diſtance from conjunction or oppoſition. In ſhort, the appearances will be the ſame as if it were not the earth which deſcribed areas proportional to the times round the ſun, but that a point, lying between the earth and moon, and very near the earth's ſurface, were deſcribing the ellipſe round the ſun, while the earth and moon revolve round this point in the courſe of a lunation, having the point always in the line between them, in the ſame manner as if they were on the extremities of a rod which turns round this point, while the point itſelf revolves round the ſun.

This then is the fact with reſpect to the motions; and the earth in a month deſcribes an orbit round this common centre of the earth and moon. It cannot do this unleſs it be continually deflected from the tangent to this orbit; therefore it is continually deflected toward the moon: and the momentum of this deflection, that is, its quantity of motion, is the ſame with that of the moon's deflection, becauſe their diſtances from the common centre are as their quantities of matter inverſely.

Appearances perfectly ſimilar to theſe oblige us to affirm that the ſun is continually deflected toward the planets. Aſtronomical inſtruments, and the art of obſerving, have been prodigiouſly improved ſince Sir Iſaac Newton's time; and the moſt ſcrupulous attention has been paid to the ſun's motion, becauſe it is to his place in the univerſe that continual reference is made in computing the place of all the planets. He is ſuppoſed at reſt in the common focus of all their orbits; and the *obſerved* diſtance of a planet from the ſun is always conſidered as the *radius vector.* If this be not the caſe, the orbital motions contained in our tables are not the abſolute motions of the planets, nor the deflections from the tangents the real deflections from abſolute rectilineal motion; and therefore the forces are not ſuch as we infer from thoſe miſtaken deflections. Accordingly Sir Iſaac Newton, induced by certain metaphyſical conſiderations, aſſumed it as a law of motion, that every action of a body A on another body B, is accompanied by an equal and contrary action of B on A. We do not ſee the propriety of this aſſertion as a metaphyſical axiom. It is perfectly conceivable that a piece of iron will always approach a magnet when in its neighbourhood; but we do not ſee that this obliges us to aſſert that *therefore* the magnet will alſo approach the iron. Thoſe who explain the phenomena of magnetiſm by the impulſe of a fluid, muſt certainly grant that there is no metaphyſical neceſſity for another ſtream of fluid impelling the magnet toward the iron. And accordingly this, and the ſimilar reciprocity in the phenomena of electricity, have *always* been conſidered as deductions of experimental philoſophy; yet we obſerve the ſame reciprocity in all the actions of ſublunary bodies; and Newton's third law of motion is received as true, and admitted as a principle of reaſoning. But we apprehend that it was haſty in this great philoſopher, and unlike his ſcrupulous caution, to extend it to the planetary motions. He did, however, extend it, and aſſerted, that as each planet was deflected toward the ſun, the ſun was equally (in reſpect of momentum) deflected toward each planet, and that his real motion was the compoſition of all thoſe ſimultaneous deflections. He aſſerted, that there was a certain point round which the ſun and his attending planets revolved; and that the orbit of a planet, which our meaſurements determined by continual reference to the ſun as to a fixed body, was not the true orbit, but conſiſted of the contemporaneous orbits of that planet and of the ſun round this fixed point. Any little ſector of the apparent orbit was greater than the correſponding ſector of the planet's true orbit in abſolute ſpace, and the apparent motion was compounded of the true motion of the planet, and the oppoſite to the true motion of the ſun. After a moſt ingenious and refined inveſtigation, he ſhowed that, notwithſtanding this great difference of the Keplerean laws from the truth, the inference, with reſpect to the law of planetary deflection, is juſt, and that not only the apparent deflections are in the inverſe duplicate ratio of the diſtances from the ſun, but that the real deflections vary in the ſame ratio of the diſtances from the fixed point, and alſo from the ſun; for he ſhewed that the diſtances from the ſun were in a conſtant ratio to the diſtances from this point. He ſhewed alſo that the ſame forces which produced the contemporaneous revolution of a planet and the ſun round the centre of the ſyſtem, would produce a revolution of the planet in a ſimilar orbit round the ſun (ſuppoſed to be held faſt in his place) at the ſame diſtance which really obtains between them, with this ſole difference, that the periodic time will be longer, in the ſubduplicate ratio of the quantity of matter in the ſun to the quantity of matter of the ſun and planet together. Areas will be deſcribed proportional to the times, and the orbit will be elliptical; but the ratio of the ſquares of the periodic times will not be the ſame with the ratio of the cubes of the diſtances, unleſs all the planets are equal.

31
Obſervations on the third law of motion.

32
Newton's extenſion of that law

Thus was the attention of aſtronomers directed to a number of *apparent* irregularities in the motion of the earth, which muſt reſult from this derangement of the ſun, which they had imagined to remain ſtedfaſt in his place. They were told what to expect, and on what poſitions of the planets the kind and quantity of every irregularity depended. This was a moſt inviting field of obſervation to a curious ſpeculatiſt; but it required the niceſt and moſt expenſive inſtruments, and an uninterrupted ſeries of long continued obſervations, ſufficient to occupy the whole of a man's time. Fortunately the accurate determination of the ſolar and lunar motions were of the utmoſt importance, nay, indiſpenſably neceſſary for ſolving the famous problem of the longitude of a ſhip at ſea: and thus the demands of commercial Europe came in aid of philoſophical curioſity, and occaſioned the erection of obſervatories, firſt at Greenwich, and ſoon after at Paris and other places, with eſtabliſhments for aſtronomers, who ſhould carefully watch the motions of the ſun and moon, not neglecting the other planets.

33
Confirmed by obſervation.

The fortunate reſult of all this ſolicitude has been the complete eſtabliſhment of the Newtonian conjecture (for ſo we muſt ſtill think it), and the verification of Newton's aſſertion, that action was accompanied, through the whole ſolar ſyſtem, by an equal and contrary reaction. All the inequalities of the ſolar motion predicted by Newton have been obſerved, although they are frequently ſo complicated that they could never have been detected, had not the Newtonian theory directed us when to find any of them pretty clear of complication, and how to aſcertain the accumulated reſult of them all in any ſtate of combination.

But in the courſe of this attention to the motions of the ſun and moon, the planets came in for a ſhare, and conſiderable deviations were found, from the ſuppoſition that all their deflections were directed to the ſun, and were in the inverſe duplicate ratio of their diſtances. The nice obſervation ſhewed, that the period of Jupiter was ſomewhat ſhorter than Kepler's law required.

A ſlight reflection ſhewed that this was no inconſiſtency; becauſe the common centre of the conjoined orbits of the Sun and Jupiter was ſenſibly diſtant from the centre of the ſun, namely, about the 1100th part of the *radius vector;* and therefore the real deflection was about a 2200th part leſs than was ſuppoſed. It was now plain that the diſtances to which the Keplerean law muſt be applied, are the diſtances, not from the ſun, but from the fixed point round which the ſun and planets revolve. This difference was too ſmall to be obſerved in Kepler's time; but the ſeeming error is only a confirmation of the Newtonian philoſophy.

But there are other irregularities which cannot be explained in this manner. The planetary orbits change their poſition; their aphelia advance, their nodes recede, their inclination to each other vary. The mean motions of Saturn and Jupiter are ſubject to conſiderable changes, which are periodical.

34
Deflection of the planets towards each other.

Sir Iſaac Newton had no ſooner diſcovered the univerſality and reciprocity of the deflections of the planets and the ſun, than he alſo ſuſpected that they were continually deflected towards each other. He immediately obtained a general notion of what ſhould be the more general reſults of ſuch a mutual action. They may be conceived in this way.

Plate VI.

Let S (fig. 5.) repreſent the ſun, E the earth, and I Jupiter, deſcribing concentric orbits round the centre of the ſyſtem. Make $IS : EA = EI^2 : SI^2$. Then, if IS be taken to repreſent the deflection of the ſun toward Jupiter, EA will repreſent the deflection of the Earth to Jupiter. Draw EB equal and parallel to SI, and complete the parallelogram EBAD. ED will repreſent the diſturbing force of Jupiter. It may be reſolved into EF, perpendicular to ES, and EG in the direction of SE. By the firſt of theſe the earth's angular motion round the ſun is affected, and by the ſecond its deflection toward him is diminiſhed or increaſed.

35
General reſult of ſuch mutual action.

In conſequence of this firſt part of the diſturbing force, the angular motion is increaſed, while the earth approaches from quadrature to conjunction with Jupiter (which is the caſe repreſented in the figure), and is diminiſhed from the time that Jupiter is in oppoſition till the earth is again in quadrature, weſtward of his oppoſition. The earth is then accelerated till Jupiter is in conjunction with the ſun; after which it is retarded till the earth is again in quadrature.

The earth's tendency to the ſun is diminiſhed while Jupiter is in the neighbourhood of his oppoſition or conjunction, and increaſed while he is in the neighbourhood of his ſtationary poſitions. Jupiter being about 1000 times leſs than the ſun, and 5 times more remote, IS muſt be conſidered as repreſenting $\frac{1}{25000}$th of the earth's deflection to the ſun, and the forces ED and EG are to be meaſured on this ſcale.

In conſequence of this change in the earth's tendency to the ſun, the aphelion ſometimes advances by the diminution, and ſometimes retreats by the augmentation. It advances when Jupiter chances to be in oppoſition when the earth is in its aphelion; becauſe this diminution of its deflection towards the ſun makes it later before its path is brought from forming an obtuſe angle with the *radius vector,* to form a right angle with it. Becauſe the earth's tendency to the ſun is, on the whole, more diminiſhed by the diſturbing force of Jupiter than it is increaſed, the aphelion of the earth's orbit advances on the whole.

In like manner the aphelia of the inferior planets advance by the diſturbing forces of the ſuperior: but the aphelion of a ſuperior planet retreats; for theſe reaſons, and becauſe Jupiter and Saturn are larger and more powerful than the inferior planets, the aphelia of them all advance while that of Saturn retreats.

In conſequence of the ſame diſturbing forces, the node of the diſturbed planet retreats on the orbit of the diſturbing planet; therefore they all retreat on the ecliptic, except that of Jupiter, which advances by retreating on the orbit of Saturn, from which it ſuffers the greateſt diſturbance. This is owing to the particular poſition of the nodes and the inclinations of the orbits.

The inclination of a planetary orbit increaſes while the planet approaches the node, and diminiſhes while the planet retires from it.

36
A peculiarity explained in the motions of Jupiter and Saturn.

M. de la Place has completed this deduction of the planetary inequalities, by explaining a peculiarity in the motions of Jupiter and Saturn, which has long employed the attention of aſtronomers. The accelerations and retardations of the planetary motions depend, as has been ſhown, on their configurations, or the relative quarters of the heavens in which they are. Thoſe of Mercury, Venus, the Earth, and Mars, ariſing from their mutual deflections; and their more remarkable deflections to the great planets Jupiter and Saturn, nearly compenſate each other, and no traces of them remain after a few revolutions: but the poſitions of the aphelia of Saturn and Jupiter are ſuch, that the retardations of Saturn ſenſibly exceed the accelerations, and the anomaliſtic period of Saturn increaſes almoſt a day every century; on the contrary, that of Jupiter diminiſhes. M. de la Place ſhows, that this proceeds from the poſition of the aphelia, and the almoſt perfect commenſurability of their revolutions; five revolutions of Jupiter making 21,675 days, while two revolutions of Saturn make 21,538, differing only 137 days.

Suppoſing this relation to be exact, the theory ſhews, that the mutual action of theſe planets muſt produce mutual accelerations and retardations of their mean motions, and aſcertains the periods and limits of the ſecular equations thence ariſing. Theſe periods include ſeveral centuries. Again, becauſe this relation is not preciſe, but the odd days nearly divide the periods already found, there muſt ariſe an equation of this ſecular equation, of which the period is immenſely longer, and the maximum very minute. He ſhews that this retardation of Saturn is now at its maximum, and is diminiſhing again, and will, in the courſe of years, change to an acceleration.

This inveſtigation of the ſmall inequalities is the moſt intricate problem in mechanical philoſophy, and has been completed only by very ſlow degrees, by the arduous efforts of the greateſt mathematicians, of whom M. de la Grange is the moſt eminent. Some of his general reſults are very remarkable.

37
Oſcillation of the planetary ſyſtem.

He demonſtrates, that ſince the planets move in one direction, in orbits nearly circular, no mutual diſturbances make any permanent change in the mean diſtances and mean periods of the planets, and that the periodic changes are confined within very narrow limits. The orbits can never deviate ſenſibly from circles. None of them ever has been or will be a comet moving in a very eccentric orbit. The ecliptic will never coincide with the equator, nor change its inclination above two degrees. In ſhort, the ſolar planetary ſyſtem oſcillates, as it were, round a medium ſtate, from which it never ſwerves very far.

38
Authenticity of the Indian aſtronomy.

This theory of the planetary inequalities, founded on the univerſal law of mutual deflection, has given to our tables a preciſion. and a coincidence with obſervation, that ſurpaſſes all expectation, and inſures the legitimacy of the theory. The inequalities are moſt ſenſible in the motions of Jupiter and Saturn; and theſe preſent themſelves in ſuch a complicated ſtate, and their periods are ſo long, that ages were neceſſary for diſcovering them by mere obſervation. In this reſpect, therefore, the theory has outſtripped the obſervations on which it is founded. It is very remarkable, that the periods which the Indians aſſign to theſe two planets, and which appeared ſo inaccurate that they hurt the credit of the ſcience of thoſe ancient aſtronomers, are now found preciſely ſuch as muſt have obtained about three thouſand years before the Chriſtian era; and thus they give an authenticity to that ancient aſtronomy. The periods which any nation of aſtronomers aſſign to thoſe two planets would afford no contemptible mean for determining the age in which it was obſerved.

The following circumſtance is remarkable: Suppoſe Jupiter and Saturn in conjunction in the firſt degree of Aries; twenty years after, it will happen in Sagittarius; and after another twenty years, it will happen in Leo. It will continue in theſe three ſigns for 200 years. In the next 200 it will happen in Taurus, Capricornus, and Virgo; in the next 200 years, it will happen in Gemini, Aquarius, and Libra; and in the next 200 years, it will happen in Cancer, Piſces, and Scorpio: then all begins again in Aries. It is highly probable that theſe remarkable periods of the oppoſitions of Jupiter and Saturn, progreſſive for 40 years, and oſcillating during 160 more, occaſioned the aſtrological diviſion of the heavens into the four *trigons*, of fire, air, earth, and water. Theſe relations of the ſigns, which compoſe a trigon, point out the repetitions of the chief irregularities of the ſolar ſyſtem.

39
Origin of the aſtrological diviſion of the heavens.

M. de la Place obſerves (in 1796,) that the laſt diſcovered planet gives evident marks of the action of the reſt; and that when theſe are computed and taken into the account of its bygone motions, they put it beyond doubt that it was ſeen by Flamſtead in 1690, by Mayer in 1756, and by Monnier in 1769.

40
Action of the comets.

We have hitherto overlooked the comets in our account of the mutual diſturbances of the ſolar ſyſtem. Their number is very great, and they go to all quarters of the univerſe: but we may conclude, from the wonderful regularity of the planetary motions, when all their own mutual actions are taken into account, that the quantity of matter in the comets is very inconſiderable. They remain but a ſhort time in the neighbourhood of the planets, and they paſs them with great rapidity. Some of them have come very near to Jupiter, but left no trace of their action in the motions of his ſatellites. They doubtleſs contribute, in general, to make the apſides of the planetary orbits advance.

41
They are affected by the planets.

On the other hand, the comets may be conſiderably affected by the planets. The very important phenomenon of the return of the comet of 1682, which was to decide whether they were revolving planets deſcribing ellipſes, or bodies which came but once into the planetary regions, and then retired for ever, cauſed the aſtronomers to conſider this matter with great care. Halley had ſhown, in a rough way, that this comet muſt have been conſiderably affected by Jupiter. Their motion near the aphelion muſt be ſo very ſlow, that a very ſmall change of velocity or direction, while in the planetary regions, muſt conſiderably affect their periods. Halley thought that the action of Jupiter might change it half a year. Mr Clairaut, by conſidering the diſturbing forces of Jupiter and Saturn through the whole revolution, ſhowed that the period then running would exceed the former nearly two years (618 days), and aſſigned the middle of April 1759 for the time of its perihelion. It really paſſed its perihelion on the 12th of March. This was a wonderful preciſion, when we reflect that the comet had been ſeen but a very few days in its former apparitions.

A comet obſerved by Mr Proſperin and others in 1771 has greatly puzzled the aſtronomers. Its motions appear to have been extremely irregular, and it certainly came ſo near Jupiter, that his momentary influence was at leaſt equal to the ſun's. It has not been recogniſed ſince that time, although there is great probability that it is continually among the planets.

42
Conſequence of a comet and planet meeting.

It is by no means impoſſible, nor highly improbable, that in the courſe of ages, a comet may actually meet one of the planets. The effect of ſuch a concourſe muſt be dreadful; a change of the axis of diurnal rotation muſt reſult from it, and the ſea muſt deſert its former bed and overflow the new equatorial regions. The ſhock and the deluge muſt deſtroy all the works of man, and moſt of the race. The remainder, reduced to miſery, muſt long ſtruggle for exiſtence, and all remembrance of former arts and events muſt be loſt, and every thing muſt be invented anew. There are not wanting traces of ſuch devaſtations in this globe: ſtrata and things are now found on mountain tops which were certainly at the bottom of the ocean in former times; remains of tropical animals and plants are now dug up in the circumpolar regions. *Tempora mutantur, et nos mutamur in illis.*

It is plain, that when we know the direction and the intenſity of the diſturbing force, we can tell what will be the accumulated effect of its action for any time. The direction is eaſily determined by means of the diſtance: but how ſhall we determine the intenſity? Since we ſee that the whole waters of the ocean are deflected toward the moon, and have ſuch probable evidence that planetary deflection is mutual; it follows, that the moon is deflected towards *every* drop of water, and that *all* the matter in one body is deflected towards *all* the matter in another body; and therefore that the deflection towards the ſun or a planet is greater or leſs in proportion to its quantity of matter. Newton indeed thought it unreaſonable to ſuppoſe that a planet was deflected to the centre of the ſun, which had no diſtinguiſhing phyſical property; and thought it more probable that the deflection of a planet to the ſun was the accumulated deflection of every particle in the planet to every particle in the ſun. But he was too ſcrupulous to take this for granted. He therefore endeavoured to diſcover what would be the ſenſible deflection of one ſphere to another, when each conſiſted of matter, every particle of which was deflected to every particle of the other with an intenſity inverſely proportional to the ſquare of the diſtance from it. By help of a moſt beautiful and ſimple proceſs, he diſcovered, that the tendency of a particle of matter to a ſpherical ſurface, ſhell, or ſolid, of uniform denſity at equal diſtances from the centre, was the ſame as if all the particles in the ſurface, ſhell, or ſolid, were united in its centre: hence it legitimately followed, that the mutual tendency of ſpherical ſurfaces, ſhells, or ſolids, was proportional to the quantities of matter in the attracting body, and inverſely as the ſquare of the diſtance of their centres; and thus the law of attraction, competent to every particle of planetary matter, was the ſame with that which *was obſerved* among ſpherical bodies conſiſting of ſuch matter. And it is remarkable, that the inverſe duplicate ratio of the diſtances is the only law that will hold, both with reſpect to ſingle particles and to globes compoſed of ſuch particles. He alſo demonſtrated, that a particle placed within a ſphere was not affected by all the ſhell, which was more diſtant than itſelf from the centre, being equally attracted on every ſide, and that it tended toward the centre of a homogeneous ſphere, on the ſurface of which it was placed, with a force proportional to its diſtance from the centre.

43 Tendency of ſpherical bodies towards each other, directly as the quantity of matter, and inverſely as the ſquare of the diſtance of their centres.

Newton ſaw a caſe in which it was poſſible to diſcover whether the tendency of the matter of which the planets conſiſted was directed to a mathematical centre void of any phyſical properties, or whether it was the reſult of its united tendency to all the matter of the planet. He demonſtrated, that if the earth conſiſted of matter which tended to the centre, it behoved it to aſſume the form of an elliptical ſpheroid, in conſequence of the centrifugal force ariſing from its diurnal motion, and that the polar axis muſt be to its equatorial diameter as 577 to 578; but if every particle tends to every other particle in the inverſe duplicate ratio of the diſtance from it, the form muſt ſtill be elliptical, but more protuberant, and the polar axis muſt be to the equatorial diameter as 230 to 231. Then only will a column of water from the pole to the centre balance a column from the equator to the centre. He alſo ſhewed what ſhould be the vibrations of pendulums in different latitudes, on both ſuppoſitions. Mathematicians were eager therefore to make thoſe experiments on pendulums, and to determine the figure of the earth by the meaſurement of degrees of the meridian in different latitudes. The reſult of their endeavours has been decidedly in favour of the mutual tendency of all matter. This has been farther confirmed by the obſervations of the mathematicians who meaſured the degrees of the meridian in Peru, and by Dr Maſkelyne in Britain, who found that a pendulum ſuſpended in the neighbourhood of a great and ſolid mountain, ſenſibly deviated from the true vertical, and was deflected toward the mountain.

44 Proportional quantities of matter in the ſun and planets determined.

From a collective view of all theſe circumſtances, Sir Iſaac Newton concluded, with great confidence, that the deflection toward any planet was the united deflection toward every particle of matter contained in it.

This enabled him to determine the intenſity of the planetary diſturbing forces, by previouſly aſcertaining the proportions of their quantities of matter. This proportion, the diſcovery of which ſeems above our reach, is eaſily aſcertained in all thoſe bodies which have others revolving round them: for the deflection of the revolving body, being occaſioned by all the matter in the central body, will be proportional *(cæteris paribus)* to the quantity of matter in the central body, and therefore will give us a meaſure of that quantity. Would we compare the quantity of matter in Jupiter with the quantity of matter in the ſun, we have only to ſuppoſe that a planet revolves round the ſun at the diſtance of Jupiter's fourth ſatellite. Kepler's third law will tell us the time of its revolution. The diſtances, in this caſe, being the ſame, the centripetal forces, and conſequently the quantities of matter in the central bodies, will be inverſely as the ſquares of the periodic times of the revolutions around them. In this way have the quantities of matter been determined for the Sun, the Earth, Jupiter, Saturn, and the laſt diſcovered planet. If the quantity in the Earth be conſidered as the unit, we have,

The Earth - - - - -	1
The newly diſcovered planet -	17,75
Saturn - - - - - -	86,16
Jupiter - - - - - -	317,1
The Sun - - - -	338343.

Thus we ſee that the ſun is incomparably bigger than any planet, having more than a thouſand times as much matter as Jupiter, the moſt maſſy of them all. There is a conſiderable uncertainty, however, in the proportion to the ſun, becauſe we do not know his diſtance nearer than within $\frac{1}{500}$th part. The proportions of the reſt to each other are more accurate. The quantities of matter in Mercury and Mars can only be gueſſed at: the quantity in Mercury may be called 0,1, and Mars may be called 0,12. Venus is ſuppoſed nearly equal to the Earth. This is concluded from the effect which ſhe produces on the preceſſion of the equinoxes and the equation of the ſun's motion. The moon is ſuppoſed to be about $\frac{1}{60}$th of the earth, from the effect ſhe produces on the tides and the preceſſion of the equinoxes, compared with thoſe produced by the ſun.

45 Sun's place and the tranſit of a planet determined exactly.

When theſe quantities of matter are introduced into the computation of the planetary inequalities, and the intenſity of the diſturbing forces aſſumed accordingly, the reſults of the computations tally ſo exactly with obſervation, that we can now determine the ſun's place for any moment within two or three ſeconds of a degree, and are certain of the tranſit of a planet within one beat of the clock!

> *Jam dubios nulla caligine prægravat error;*
> *Queis ſuperum penetrare domos atque ardua cœli*
> *Scandere ſublimis genii conceſſit acumen.*
>
> HALLEY.

46 Progreſs of Newton's diſcovery of

Sir Iſaac Newton having already made the great diſcovery of an univerſal and mutual deflection of all the matter in the ſolar ſyſtem, was one day ſpeculating on this ſubject, and comparing it with other deflections which he obſerved among bodies, ſuch as magnets, &c. He conſidered terreſtrial gravity as a force of this kind. By the weight of terreſtrial bodies they kept united with the earth. By its weight was the water of the ocean formed into a ſphere. This force extended, without any remarkable diminution, to the tops of the higheſt mountains. Might it not reach much farther? May it not operate even at the diſtance of the moon? In the ſame manner that the planetary force deflects the moon from the tangent to her orbit, and cauſes her to deſcribe an ellipſe, the weight of a cannon ball deflects it from the line of its direction, and makes it deſcribe a parabola. What if the deflecting force which incurvates her path towards the earth be the ſimple weight of the moon? If the weight of a body be the ſame with the general planetary force, it will diminiſh as the ſquare of its diſtance from the earth increaſes. Therefore, ſaid he to himſelf, ſince the diſtance of the moon from the centre of the earth is about 50 times greater than the diſtance of the ſtone which I throw from my hand, and which is deflected 16 feet in one ſecond, the weight of this ſtone, if taken up to the height of the moon, ſhould be reduced to the 2500th part, and ſhould there deflect $\frac{1}{2500}$th of 16 feet in a ſecond; and the moon ſhould deflect as much from the tangent in a ſecond. Having the dimenſions, as he thought, of the moon's orbit, he immediately computed the moon's deflection in a ſecond; but he found it conſiderably different from what he wiſhed it to be. He therefore concluded that the planetary force was not the weight of the planet. For ſome years he thought no more of it; but one day, in the Royal Society, he heard an account read of meaſurements of a degree of the meridian, which ſhowed him that the radius of the earth and the diſtance of the moon were very different from what he had believed them to be. When he went home he repeated his computation, and found, that the deflection of a ſtone was to the ſimultaneous deflection of the moon as the ſquare of the moon's diſtance from the centre of the earth to the ſquare of the ſtone's diſtance. Therefore the moon is deflected by its weight; and the fall of a ſtone is juſt a particular inſtance of the exertion of the univerſal planetary force. This computation was but roughly made at firſt; but it was this coincidence that excited the philoſopher to a more attentive review of the whole ſubject. When every circumſtance which can affect the reſult is taken into account, the coincidence is found to be moſt accurate. The fall of the ſtone is not the full effect of its weight; for it is diminiſhed by the rotation of the earth round its axis: It is alſo diminiſhed by the weight of the air which it diſplaces: It is alſo diminiſhed by its tendency to the moon. On the other hand, the moon does not revolve round the earth, but round a common centre of the earth and moon, and its period is about $\frac{1}{120}$th ſhorter than if it revolved round the earth; and the moon's deflection is affected by the ſun's diſturbing force. But all theſe corrections can be accurately made, and the ratio of the full weight of the ſtone to the full deflection of the moon aſcertained. This has been done.

Terreſtrial gravity therefore, or that power by which bodies fall or preſs on their ſupports, is only a particular inſtance of that general tendency by which the planets are retained in their orbits. Bodies may be ſaid to *gravitate* when they give indications of their being *gravis* or heavy, that is, when they fall or preſs on their ſupports; therefore the planets may be ſaid to gravitate when they give ſimilar indications of the ſame tendency by their curvelineal motions. The general FACT, that the bodies of the ſolar ſyſtem are mutually deflected towards each other, may be expreſſed by the verbal noun GRAVITATION. Gravitation does not expreſs a quality, but an event, a deflection, or a preſſure.

47 The univerſal law of gravitation,

The weight of a terreſtrial body, or its preſſure on its ſupport, is the effect of the accumulated gravitation of all its particles; for bodies of every kind of matter fall equally faſt. This has been aſcertained with the utmoſt accuracy by Sir Iſaac Newton, by comparing the vibrations of pendulums made of every kind of matter. Therefore their united gravitation is proportional to their quantity of matter; and we have concluded, that every atom of terreſtrial matter is heavy, and equally heavy. We extend this concluſion to the ſun and planets, and ſay, that the obſerved gravitation of a planet is the united gravitation of every particle. Therefore Sir Iſaac Newton inferred, from a collective view of all the phenomena, that *all matter gravitates to* all matter with a force in the inverſe duplicate ratio of the diſtance.

But we do not think that this inference is abſolutely certain. We acknowledge that the experiments on pendulums, conſiſting of a vaſt variety of terreſtrial matter, all of which performed their oſcillations in equal times, demonſtrate that the acceleration of gravity on thoſe pendulums was proportional to their quantities of matter, and that equal gravitation may be affirmed of all terreſtrial matter.

The elliptical motion of a planet is full proof that the accelerating power of its gravity varies in the inverſe duplicate ratio of the diſtance; and the proportionality of the ſquares of the periods to the cubes of the diſtances, ſhows that the whole gravitations of the planets vary by the ſame law. But this third obſervation of Kepler might have been the ſame, although the gravitation of a particle of matter in Jupiter had been equal to that of a particle of terreſtrial matter, provided that all the matter in Jupiter did not gravitate. If

$\frac{1}{25}$th of Jupiter had been ſuch gravitating matter, his deflection from the tangent of his orbit would have been the ſame as at preſent, and the time of his revolution would have been what we obſerve. In order that the third law of Kepler may hold true of the planetary motions, no more is required than that the accumulated gravitation of the planet be proportional to its quantity of matter, and thus the matter which does not gravitate will be compenſated by the ſuperior gravitation of the reſt.

But becauſe we have no authority for ſaying that there is matter which gravitates differently from the reſt, or which does not gravitate, we are entitled to ſuppoſe that gravity operates alike on all matter.

48
Which is the ultimatum of his philoſophy.

And this is the ultimatum of the Newtonian philoſophy, that the ſolar ſyſtem conſiſts of bodies compoſed of matter, every particle of which is, in fact, continually deflected by its weight towards every other particle in the ſyſtem; and that this deflection, or actual deviation, or actual preſſure, tending to deviation from uniform rectilineal motion, is in the inverſe duplicate ratio of the diſtance.

49
Objections to the law of gravitation ill-founded.

This doctrine has been called *the ſyſtem of univerſal gravitation*; and it has been blamed as introducing an unphiloſophical principle into ſcience. Gravitation is ſaid to be an occult quality; and therefore as unfit for the explanation of phenomena as any of the occult qualities of Ariſtotle. But this reproach is unfounded; gravitation does not expreſs any quality whatever, but a matter of fact, an event, an actual deflection, or an actual preſſure, producing an actual deflection of the body preſſed. Theſe are not occult, but matters of continual obſervation. True, indeed, Newton does not deny, although he does not poſitively ſay, that this deflection, preſſure, or gravitation, is an effect having a cauſe. *Gravity* is ſaid to be this cauſe. Gravity is the *being gravis or heavy*, and gravitation is the *giving indications of being heavy*. Heavineſs therefore is the word which expreſſes *gravitas*, and our notion of the cauſe of the planetary deflections is the ſame with our notion of heavineſs. This may be indiſtinct and unſatisfactory to a mind faſtidiouſly curious; but nothing can be more familiar. The planet is deflected, *becauſe it is heavy*. We are ſuppoſed to explain the fall of a ſtone through water very ſatisfactorily, and without having recourſe to any occult quality, when we ſay that it is heavier than the water; and we explain the riſe of a piece of cork, when we ſay that it is not ſo heavy as the water. The explanations of the mutual actions of the planets are equally ſatisfactory, founded on the ſame principles, and equally free from all ſophiſtry or employment of occult cauſes. The weight of a body is not its heavineſs, but the effect of its heavineſs. It is a gravitation, an actual preſſure, indicated by its balancing the ſuppoſed heavineſs of another body, or by its balancing the known elaſticity of a ſpring, or by balancing any other natural power. It is ſimilar to the preſſure which a magnet exerts on a piece of iron. This may perhaps be produced by the impulſe of a ſtream of fluid; ſo may the weight of a heavy body. But we do not concern ourſelves with this queſtion. We gain a moſt extenſive and important knowledge by our knowledge of this univerſal law; for we can now explain every phenomenon, by pointing out how it is contained in this law; and we can predict the whole events of the ſolar ſyſtem with unerring exactneſs. This ſhould ſatisfy the moſt inquiſitive mind.

50
Our knowledge of that law ſatisfactory.

But, *nitimur in vetitum, ſemper cupimuſque negata.* There ſeems to be a fatal and ruinous diſpoſition in the human mind, a ſort of *priapiſm* of the underſtanding, that is irritated by every interdict of natural imperfection. We would take a microſcope to look at light; we would *know* what *knowing* is, and we would *weigh heavineſs*.

51
Vain attempts to account for it.

All who are acquainted with the writings of Ariſtotle have ſome notion of his whimſical opinions on this ſubject. He imagines that the planets are conducted in their orbits by a ſort of intelligences, ὁσπερ Ψυχαι, which animate the orbs that wheel them round. Although this crude conception met with no favour in later times, another, not more reaſonable, was maintained by Leibnitz, who called every particle of matter a *monad*, and gave it a perception of its ſituation in the univerſe, of its diſtance and direction from every other, and a power and will to move itſelf in conformity to this ſituation, by certain conſtant laws. This ὁσπερ Ψυχη in the Monad is nothing but an aukward ſubſtitute for the principle of gravitation, which the learned inſiſted that Newton placed in every particle of matter as an innate power, and which they reprobated as unphiloſophical. But in what reſpect this perception and active propenſity is better, we do not perceive. It is more complex, and involves every notion that is reprehenſible in the other; and it offers no better explanation of the phenomena.

But Newton is equally anxious with other philoſophers not to aſcribe gravity to matter as an innate inherent property. In a letter to Dr Bently, he earneſtly requeſts him not to charge him with ſuch an abſurd opinion. It is an avowed principle, that nothing can *act* on any thing that is at a diſtance; and this is conſidered as an intuitive axiom. But it is ſurely very obſcure; for we cannot obtain, or at leaſt convey, clear notions of the terms in which it is expreſſed. The word *act* is entirely figurative, borrowed from animal exertions; it is therefore unlike the expreſſion of any thing intitled to the appellation of *intuitive*. If we try to expreſs it without figure, we find our confidence in its certainty greatly diminiſhed. Should we ſay that the condition of a body A cannot depend on another body B that is at diſtance from it, we believe that no perſon will ſay that he makes this aſſertion from perceiving the abſurdity of the contrary propoſition. In the demonſtration, as it is called, of the perſeverance of a body in a ſtate of reſt, the only argument that is offered is, that no cauſe can be aſſigned why it ſhould move in one direction rather than in another: but ſhould any one ſay that another body is near it, to the right hand, and that this is a ſufficient reaſon for its moving that way, we know no method by which this aſſertion can be ſhown to be falſe.

Such, however, has been the uniform opinion of philoſophers. *Nihil movetur* (ſays Leibnitz) *niſi a contiguo et moto.* The celebrated mathematician Euler having diſcovered, as he thought, the production of a preſſure, like gravity, from motion, ſays, "as motion may ariſe from preſſing powers, ſo we have ſeen that preſſing powers may ariſe from motion. We ſee that both exiſt in the univerſe. It is the buſineſs of a philoſopher to diſcover, by reaſon and obſervation, which is the origin of and is of the ſame kind with the production of motion by gravity.

61 Intervening fluids multiply difficulties.

Therefore no explanation of gravitation can be derived from any hypotheſis whatever of intervening fluids. They only ſubſtitute millions of bodies for one, and ſtill leave the action *e diſtanti* the ſame difficulty as before. It is not in the leaſt neceſſary that we ſhall be able to conceive how a particle of matter can be influenced by another at a diſtance; if we have diſcovered in every inſtance the preciſe degree and direction of the effect of this influence, we have made a moſt important addition to our knowledge of nature; and our ſucceſs in the caſe of the power of gravity ſhould make us aſſiduous in our endeavours to diſcover, from the phenomena, the laws which regulate the other actions *e diſtanti*, which obſervation is daily finding out. A knowledge equally accurate of the law of magnetic and electric action may enable us to give theories of magnetiſm and electricity equally exact with the Newtonian theory of gravitation.

Having, we hope, evinced the truth of this theory, by following out the inveſtigations to which Newton was gradually led, we might proceed to conſider, in order, the complicated and ſubordinate phenomena which depend on it. The lunar and planetary inequalities are the ſubjects that naturally come firſt in our way; but they have already been explained in all the detail that this conciſe account will admit, as they occurred to Newton as teſts of the truth of his conjecture. If the law be ſuch as he ſuſpected, its conſequences muſt be ſo and ſo; if the celeſtial motions do not agree with them, the law muſt be rejected. We ſhall not repeat any thing therefore on this head, but confine our obſervations to ſuch applications of the theory of univerſal gravitation as newly diſcovered objects, or the improvement of aſtronomical obſervation and of fluxionary analyſis, have enabled us to make ſince the time of Newton.

The ſubſerviency of the eclipſes of Jupiter's ſatellites to geography and navigation had occaſioned their motions to be very carefully obſerved, ever ſince theſe uſes of them were firſt ſuggeſted by Galileo, and their theory is as far advanced as that of the primary planets. It has peculiar difficulties. Being very near to Jupiter, the great deviation of his figure from perfect ſphericity makes the relation between their diſtances from his centre and their gravitations toward it vaſtly complicated. But this only excited the mathematicians ſo much the more to improve their analyſis; and they ſaw, in this little ſyſtem of Jupiter and his attendants, an epitome of the ſolar ſyſtem, where the great rapidity of the motions muſt bring about in a ſhort time every variety of configuration or relative poſition, and thus give us an example of thoſe mutual diſturbances of the primary planets, which require thouſands of years for the diſcovery of their periods and limits. We have derived ſome very remarkable and uſeful pieces of information from this inveſtigation; and have been led to the diſcovery of the eternal durability of the ſolar ſyſtem, a thing which Newton greatly doubted of.

62 Eternal durability of the ſolar ſyſtem

Mr Pound had obſerved long ago, that the irregularities of the three interior ſatellites were repeated in a period of 437 days; and this obſervation is found to be juſt to this day.

247 revolutions of the firſt occupy	437 d.	3 h.	44′
123	ſecond	437	3	42
61	third	437	3	36
26	fourth	435	14	16

This naturally led mathematicians to examine their motions, and ſee in what manner their relative poſitions or configurations, as they are called, correſponded to this period: and it is found, that the mean longitude of the firſt ſatellite, *minus* thrice the mean longitude of the ſecond, *plus* twice the mean longitude of the third, always made 180 degrees. This requires that the mean motion of the firſt, added to twice that of the third, ſhall be equal to thrice the mean motion of the ſecond. This correſpondence of the mean motions is of itſelf a ſingular thing, and the odds againſt its probability ſeems infinitely great; and when we add to this the particular poſitions of the ſatellites in any one moment, which is neceſſary for the above conſtant relation of their longitudes, the improbability of the coincidence, as a thing quite fortuitous, becomes infinitely greater. Doubts were firſt entertained of the coincidence, becauſe it was not indeed accurate to a ſecond. The reſult of the inveſtigation is curious. When we follow out the conſequences of mutual gravitation, we find, that although neither the primitive motions of projection, nor the points of the orbit from which the ſatellites were projected, were *preciſely* ſuch as ſuited theſe obſerved relations of their revolutions and their contemporaneous longitudes; yet, if they differed from them only by very minute quantities, the mutual gravitations of the ſatellites would in time bring them into thoſe poſitions, and thoſe ſtates of mean motion, that would induce the obſerved relations; and when they are once induced they will be continued for ever. There will indeed be a ſmall equation, depending on the degree of unſuitableneſs of the firſt motions and poſitions; and this cauſes the whole ſyſtem to oſcillate, as it were a little, and but a very little way on each ſide of this exact and permanent ſtate. The permanency of theſe relations will not be deſtroyed by any ſecular equations ariſing from external cauſes; ſuch as the action of the fourth ſatellite, or of the ſun, or of a reſiſting medium; becauſe their mutual actions will diſtribute this equation as it did the original error.

This curious reſult came into view only by degrees, as analyſis improved and the mathematicians were enabled to manage more complicated formulas, including more terms of the infinite ſerieſes that were employed to expreſs the different quantities. It is to M. de la Grange that we are indebted for the completion of the diſcovery of the permanency of the ſyſtem in a ſtate very little different from what obtains in any period of its exiſtence. Although this required all the knowledge and addreſs of this great mathematician, in the management of the moſt complicated analyſis, the evidence of its truth may be perceived by any perſon acquainted with the mere elements of fluxionary geometry. The law of the compoſition of forces enables us to expreſs every action of the mutual forces of the ſun and planets by the ſines and coſines of circular arches, which increaſe with an uniform motion, like the perpetual lapſe of time. The nature of the circle ſhows, that the variations of the ſines and coſines are proportional to the coſines and ſines of the ſame arches. The variations of their ſquares, cubes, or other powers, are proportional to the ſines or coſines of the doubles or triples, or other multiples of the ſame arches. Therefore ſince the infinite ſerieſes which expreſs thoſe actions of forces, and their variations, include only ſines and coſines, with their powers and fluxions, it follows, that all accumulated forces, and variations of forces, and variations of variations, through infinite orders, are ſtill expreſſible by repeated ſums of ſines or coſines, correſponding to arches which are generated by going round and round the circle. The analyſt knows that theſe quantities become alternately poſitive and negative; and therefore, in whatever way they are compounded by addition of themſelves, or their multiplies, or both, we muſt always arrive at a period after which they will be repeated with all their intermediate variations. It may be extremely difficult, it may be impoſſible, in our preſent ſtate of mathematical knowledge, to aſcertain all thoſe periods. It has required all the efforts of all the geniuſes of Europe to manage the formulas which include terms containing the fourth and fifth powers of the eccentricities of the planetary orbits. Therefore the periods which we have already determined, and the limits to which the inequalities expreſſed by ſecular equations arrive, are ſtill ſubjected to ſmaller corrections of incomparably longer periods, which ariſe from the terms neglected in our formulas. But the correction ariſing from any neglected term has a period and a limit; and thus it will happen that the ſyſtem works itſelf into a ſtate of permanency, containing many intervening apparent anomalies. The elliptical motion of the earth contains an anomaly or deviation from uniform circular motion; the action of Jupiter produces a deviation from this elliptical motion, which has a period depending on the configuration of the three bodies; Saturn introduces a deviation from this motion, which has alſo a period; and ſo on.

There is another accurate adjuſtment of motions which has attracted attention, as a thing in the higheſt degree improbable, in events wholly independent on each other. This is the exact coincidence of the period of the moon's revolution round the earth with that of her rotation round her own axis. The ellipticity or oval ſhape of the moon differs ſo inſenſibly from a ſphere, that if the original rotation had differed conſiderably from the period of revolution, the pendular tendency to the earth could never have operated a change: but if the difference between thoſe two motions was ſo ſmall, that the pendular tendency to the line joining the centres of the earth and moon was able to overcome it after ſome time, the pole of the lunar ſpheroid would deviate a little from the line joining the earth and moon, and then be brought back to it with an accelerated motion; would paſs it as far on the other ſide, and then return again, vibrating perpetually to each ſide of the mean poſition of the *radius vector*. The extent of this vibration would depend on the original difference between the motion of rotation and the mean motion of revolution. This difference muſt have been very ſmall, becauſe this *pendular vibration* is not ſenſible from the earth. The obſerved LIBRATION of the moon is preciſely what ariſes from the inequality of her orbital motion. For the ſame reaſons, the effects of the ſecular equations of the moon (which would, in the courſe of ages, have brought her whole ſurface into our view, had her rotation been ſtrictly uniform) are counteracted by her pendular tendency, which has a force ſufficient to alter her rotation by nearly the ſame ſlow and inſenſible changes that obtain in her mean motions. The ſame cauſes alſo preſerve the nodes of her equator and of her orbit in the ſame points of the ecliptic. The complete demonſtration of this is perhaps the moſt delicate and elegant ſpecimen that has been given of the modern analyſis. We owe it to M. de la Grange: and he makes it appear that the figure of the moon is not that which a fluid ſphere would acquire by its gravitation to the earth; it muſt be the effect of a more conſiderable ellipticity, or internal inequality of denſity.

63
Depends on the law of planetary deflection,

This permanency of the ſyſtem, within very narrow limits of deviation from its preſent ſtate, depends entirely on the law of planetary deflection. Had it been directly or inverſely as the diſtance, the deviations would have been ſuch as to have quickly rendered it wholly unfit for its preſent purpoſes. They would have been very great, had the planetary orbits differed much from circles; nay, had ſome of them moved in the oppoſite direction. The ſelection of this law, and this form of the orbits, ſtrikes the mind of a Newton, and indeed any heart poſſeſſed of ſenſibility to moral or intellectual excellence, as a mark of wiſdom prompted by benevolence. But De la Place and others, infected with the *Theophobia Gallica* engendered by our licentious deſires, are eager to point it out as a mark of fataliſm. They ſay, that it is eſſential to all qualities that are diffuſed from a centre to diminiſh in the inverſe duplicate ratio of the diſtance. But this is falſe, and *very falſe:* it is a mere geometrical conception. We indeed ſay, that the denſity of illumination decreaſes in this proportion; but who ſays that this is a quality? Whether it be conſidered as the emiſſion of luminous corpuſcles, or an undulation of an elaſtic fluid, it is not a quality emanating from a centre: and even in this eſtimation, it ſeems gratuitous, whether we ſhall conſider the baſe of the luminous pyramid, or its whole contents, as the expreſſion of the quantity. Nay, if all qualities muſt diminiſh at this rate, all action *e diſtanti* muſt do the ſame; for when the diſtances bear any great proportion to the diameters of the particles, their action deviates inſenſibly from this law, and is perceived only by the accumulation of its effects after a long time. It is only thus that the effects of the oblate figure of Jupiter are perceived in the motion of his ſatellites. The boaſted ſound philoſophy which ſees fatal neceſſity where the *moſt ſucceſsful ſtudents of nature* ſaw moral excellence, has derived very little credit or title to the name of *wiſdom*, by letting looſe all thoſe propenſities of the human heart which are eſſentially deſtructive of ſocial happineſs. Theſe propenſities were always known to lurk in the heart of man; and thoſe ſurely were the wiſeſt who laboured to keep them in check by the influence of moral principles, and particularly by cheriſhing that diſpoſition of the human heart which prompts us to ſee contrivance wherever we ſee nice and refined adjuſtment of means to ends; and, from the admirable beauty of the ſolar ſyſtem, to cry out,

64
And evinces the wiſdom of the Creator.

"Theſe are thy glorious works, Parent of good!
"Almighty, thine this univerſal frame,
"Thus wond'rous fair; thyſelf how wond'rous then!
"Unſpeakable, who ſitt'ſt above theſe heavens,
"To us inviſible, or dimly ſeen
"In theſe thy loweſt works; yet theſe declare
"Thy goodneſs beyond thought, and power divine."
Par. Loſt, b. v.

"But wandering oft, with brute unconſcious gaze,
"Man marks not THEE, marks not the mighty hand
"That, ever buſy, wheels the ſilent ſpheres."
THOMPSON.

65 Saturn's ring.

The moſt important addition (in a philoſophical view) that has been made to aſtronomical ſcience ſince the diſcovery of the aberration of light and the nutation of the earth's axis, is that of the rotation of Saturn's ring. The ring itſelf is an object quite ſingular; and when it was diſcovered that all the bodies which had any immediate connection with a planet were heavy, or gravitated toward that planet, it became an intereſting queſtion, what was the nature of this ring? what ſupported this immenſe arch of heavy matter without its reſting on the planet? what maintains it in perpetual concentricity with the body of Saturn, and maintains its ſurface in one invariable poſition?

The theory of univerſal gravitation tells us what things are poſſible in the ſolar ſyſtem; and our conjectures about the nature of this ring muſt always be regulated by the circumſtance of its gravitation to the planet. Philoſophers had at firſt ſuppoſed it to be a luminous atmoſphere, thrown out into that form by the great centrifugal force ariſing from a rotation: but its well defined edge, and, in particular, its being two very narrow rings, extremely near each other, yet perfectly ſeparate, rendered this opinion of its conſtitution more improbable.

66 Diſcovery of Dr Herſchel relating to it.

Dr Herſchel's diſcovery of brighter ſpots on its ſurface, and that thoſe ſpots were permanent during the whole time of his obſervation, ſeems to make it more probable that the parts of the ring have a ſolid connection. Mr Herſchel has diſcovered, by the help of thoſe ſpots, that the ring turns round its axis, and that this axis is alſo the axis of Saturn's rotation. The time of rotation is 10h. $32\frac{1}{4}'$. But the other circumſtances are not narrated with the preciſion ſufficient for an accurate compariſon with the theory of gravity. He informs us, that the radii of the four edges of the ring are 590, 751, 774, 830, of a certain ſcale, and that the angle ſubtended by the ring at the mean diſtance from the earth is $46\frac{2}{3}''$. Therefore its elongation is $23\frac{1}{3}''$. The elongation of the ſecond Caſſinian ſatellite is 56″, and its revolution is 2d. 17h. 44′. This ſhould give, by the third law of Kepler, 17h. 10′ for the revolution of the outer edge of the ring, or rather of an atom of that edge, in order that it may maintain itſelf in equilibrio. The ſame calculation applied to the outer edge of the inner ring gives about 13h. 36′; and we obtain 11h. 16′ for the inner edge of this ring. Such varieties are inconſiſtent with the permanent appearance of a ſpot. We may ſuppoſe the ring to be a luminous fluid or vapour, each particle of which maintains is ſituation by the law of planetary revolution. In ſuch a ſtate, it would conſiſt of concentric ſtrata, revolving more ſlowly as they were more remote from the planet, like the concentric ſtrata of a vortex, and therefore having a relative motion incompatible with the permanency of any ſpot. Beſides, the rotation obſerved by Herſchel is too rapid even for the innermoſt part of the ring. We think therefore that it conſiſts of cohering matter, and of conſiderable tenacity, at leaſt equal to that of a very clammy fluid, ſuch as melted glaſs.

We can tell the figure which a fluid ring muſt have, ſo that it may maintain its form by the mutual gravitation of its particles to each other, and their gravitation to the planet. Suppoſe it cut by a meridian. It may be in equilibrio if the ſection is an ellipſe, of which the longer axis is directed to the centre of the planet, and very ſmall in compariſon with its diſtance from the centre of the planet, and having the revolution of its middle round Saturn, ſuch as agrees with the Keplerean law. Theſe circumſtances are not very conſiſtent with the dimenſions of Saturn's inner ring. The diſtance between the middle of its breadth and the centre of Saturn is 670, and its breadth is 161′, nearly one-fourth of the diſtance from the centre of Saturn. De la Place ſays, that the revolution of the inner ring obſerved by Herſchel is very nearly that required by Kepler's law: but we cannot ſee the grounds of this aſſertion. The above compariſons with the ſecond Caſſinian ſatellite ſhows the contrary. The elongation of that ſatellite is taken from Bradley's obſervations, as is alſo its periodic time. A ring of detached particles revolving in 10h. $32\frac{1}{4}'$ muſt be of much ſmaller diameter than even the inner edge of Saturn's ring. Indeed, the quantity of matter in it might be ſuch as to increaſe the gravitation conſiderably; but this would be ſeen by its diſturbing the ſeventh and ſixth ſatellites, which are exceedingly near it.

67 Its probable conſiſtency

We cannot help thinking therefore that it conſiſts of matter which has very conſiderable tenacity. An equatorial zone of matter, tenacious like melted glaſs, and whirled briſkly round, might be thrown off, and, retaining its great velocity, would ſtretch out while whirling, enlarging in diameter and diminiſhing in thickneſs or breadth, or both, till the centrifugal force was balanced by the united force of gravity and tenacity. We find that the equilibrium will not be ſenſibly diſturbed by conſiderable deviations, ſuch as unequal breadth, or even want of flatneſs. Such inequalities appear on this ring at the time of its diſparition, when its edge is turned to the ſun or to us. The appearances of its different ſides are then conſiderably different.

Such a ring or rings muſt have an oſcillatory motion round the centre of Saturn, in conſequence of their mutual action, and the action of the ſun, and their own irregularities: but there will be a certain poſition which they have a tendency to maintain, and to which they will be brought back, after deviating from it, by the ellipticity of Saturn, which is very great. The ſun will occaſion a nutation of Saturn's axis and a preceſſion of his equinoxes, and this will drag along with it both the rings and the neighbouring ſatellites.

The atmoſphere which ſurrounds a whirling planet cannot have all its parts circulating according to the third law of Kepler. The mutual attrition of the planet, and of the different ſtrata, ariſing from their different velocities, muſt accelerate the ſlowly moving ſtrata, and retard the rapid, till all acquire a velocity proportional to their diſtance from the axis of rotation; and this will be ſuch that the momentum of rotation of the planet and its atmoſphere remains always the ſame. It will ſwell out at the equator, and ſink at the poles, till the centrifugal force at the equator balances the weight of a ſuperficial particle. The greateſt ratio which the equatorial diameter can acquire to the polar axis is that of four to three, unleſs a coheſive force keeps the particles united, ſo that it conſtitutes a liquid, and not an elaſtic fluid like air; and an elaſtic fluid cannot form an atmoſphere bounded in its dimenſions, unleſs there be a certain rarity which takes away all elaſticity. If the equator ſwells beyond the dimenſion which makes the gravitation balance the centrifugal force, it muſt immediately diſſipate.

If we ſuppoſe that the atmoſphere has extended to this limit, and then condenſes by cold, or any chemical

or

68
And origin.

or other cauſe different from gravity, its rotation neceſſarily augments, preferring its former momentum, and the limit will approach the axis; becauſe a greater velocity produces a greater centrifugal force, and requires a greater gravitation to balance it. Such an atmoſphere may therefore deſert, in ſucceſſion, zones of its own matter in the plane of its equator, and *leave* them revolving in the form of rings. It is not unlikely that the rings of Saturn may have been furniſhed in this very way; and the zones, having acquired a common velocity in their different ſtrata, will preſerve it; and they are ſuſceptible of irregularities ariſing from local cauſes at the time of their ſeparation, which may afford permanent ſpots.

69
It may furniſh the means of diſcovering the nature of light.

We think that the rotation of Saturn's ring affords ſome hopes of deciding a very important queſtion about the nature of light. If light be the propagation of elaſtic undulations, its velocity depends entirely on the elaſticity and denſity of the fluid; but if it be the emiſſion of corpuſcles, their velocity may be affected by other cauſes. The velocity of Saturn's ring is $\frac{50}{63}$ of that of the earth in its orbit, and therefore about $\frac{1}{10000}$ of the velocity of light. The weſtern extremity (to us in the northern regions) is moving from us, and the eaſtern is moving toward us. If light, by which we ſee it, be reflected like an elaſtic ball from an elaſtic body, there will be an exceſs in the velocity of the light by which we ſee the eaſtern limb above the velocity of the light by which we ſee the weſtern limb. This exceſs will be $\frac{1}{2500}$ of the mean velocity of light. This ſhould be diſcovered by a difference in the refraction of the two lights. If an acromatic priſm could be made to refract fourteen degrees, and if Saturn be viewed thro' a teleſcope with this priſm placed before it, there ſhould be a change of ſhape amounting to ſixteen ſeconds; if the axis of the priſm be parallel to the longer axis of the ring, it will diſtort it prodigiouſly, and give it an oblique poſition.

A ſimilar effect will be produced by placing the priſm between the eye-glaſs and the image in the focus of the object-glaſs.

Our expectation is founded on this unqueſtionable principle in dynamics, that when a particle of light paſſes through the active ſtratum of a tranſparent body which refracts light toward the perpendicular, the addition made to the ſquare of its velocity by the refracting forces is equal to the ſquare of the velocity which thoſe forces would communicate to a particle at reſt on the ſurface of this refracting ſtratum of the tranſparent body. Therefore if the velocity of the incident light be increaſed, the ratio of the ſine of incidence to the ſine of refraction will be diminiſhed. It is conſonant to common ſenſe, that when the incident light has a greater velocity, it paſſes more rapidly through the attracting ſtratum, and a ſmaller addition is made to the velocity. When the velocity of the incident light is 10000 times greater than that of the earth's annual motion, the ſine of incidence is to the ſign of refraction in glaſs as 20 to 31, or as 10000 to 15500. If this be increaſed $\frac{1}{2500}$, making it 10004, the ratio will be that of 10004 to 15502,62, or of 10000 to 15496,4. The difference between the refractions of the light from the eaſtern and weſtern extremities of the ring will be, to all ſenſe, the ſame, if the velocity of the one be diminiſhed to 9998, and the other increaſed to 10002.

70
Probable reaſon why we ſee no atmoſphere about the moon.

We may juſt add here, by the way, that the action of another body may conſiderably change the conſtitution of this atmoſphere. Thus, ſuppoſing that the moon had originally an atmoſphere, the limit will be that diſtance from the moon where the centrifugal force, ariſing from the moon's rotation, added to the gravitation to the earth, balances the gravitation to the moon. If the moon be $\frac{1}{59}$th of the earth, this limit will be about $\frac{1}{9}$th of the moon's diſtance from the earth. If at this diſtance the elaſticity of the atmoſphere is not annihilated by its rarefaction, it will be all taken off by the earth, and accumulate round it. This may be the reaſon why we ſee no atmoſphere about the moon.

What has been ſaid in the article TIDE (Encycl.), will explain the trade-winds on the earth and in Jupiter and Saturn. On the earth they are increaſed by the expanſion of the air by heat. This cauſes it to riſe in the parts warmed by the ſun, and flow off toward the poles, where it is again cooled and condenſed. The under ſtratum of colder and denſer air is continually flowing in from the poles. This having leſs velocity of circulation than the equatorial parts of the earth, muſt have a relative motion contrary to that of the earth, or from eaſt to weſt, and this muſt augment the current produced by gravitation.

71
All the mechanical phenomena of the ſolar ſyſtem flow from one ſimple principle.

THUS we ſee that all the mechanical phenomena of the ſolar ſyſtem, whether relating to the revolutions round the various centres of gravitation, or to the figure of the planets and the oſcillations of the fluids which cover them, or to the rotations round their reſpective axes—are neceſſary conſequences of one ſimple principle of a gravitation in every particle, decreaſing in the reciprocal duplicate ratio of the diſtance. We ſee that this, combined with a primitive projection, will produce every motion that we obſerve. It was not neceſſary, as Copernicus imagined, to impreſs three motions on the earth; one, by which it was made to revolve round the ſun; a ſecond, cauſing it to turn round an axis inclined to that of its orbit; and a third, by which this axis deſcribed that conic ſurface which forms the preceſſion of the equinoxes. One impulſe, not paſſing through the centre of the earth, nor in the plane of the ecliptic, will produce the two firſt motions, and the protuberant matter produced by the rotation will generate the third motion, by the tendency of its parts to the other heavenly bodies. Without this principle, the elliptic motion of the planets and comets, their various inequalities, ſecular or periodical, thoſe of the moon and of the ſatellites of Jupiter, the preceſſion of the equinoxes, the nutation of the earth's axis, the figure of the earth, the undulations of its ocean—all would have been imperfectly known, as matters of fact, wholly different from each other, and ſolitary and unconnected. It is truly deſerving admiration, that ſuch an immenſe variety of important phenomena flow ſo palpably from one principle, of ſuch ſimplicity, and ſuch univerſality, that no phenomenon is now left out unexplained, and predicted with a certainty almoſt equal to actual obſervation.

Quæ toties animos veterum torſêre ſophorum,
Quæque ſcholas hodie rauco certamine vexant
Obvia conſpicimus, nubem pellente Matheſi,
Surgite mortales, terrenas miltete curas,
Atque hinc cœligenæ vires dignoſcite mentis,
A pecudum vitâ longe lateque remotæ.

A New

A New Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred;

Formed from Obſervations made in the Obſervatory at Gotha.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Aſcenſion in Time.			Annual Variation in R. A. and in Time.	Medium Declination.			Medium Right Aſcenſion in Equat. Part.			Annual Variation in R. A.
			h	′	″ $\frac{1}{100}$	″ $\frac{1}{1000}$	°	′	Nor. Sou.	°	′	″ $\frac{1}{100}$	″ $\frac{1}{100}$
						+							+
1	88 γ Pegaſus	2	0	2	56,79	3, 063	14	4	N	0	44	11,85	45, 95
2	8 ι Cetus	3	0	5	13,51	3, 059	9	57	S	2	18	22,66	45, 89
3	15 κ Caſſiopea	4	0	21	45,12	3, 301	61	50	N	5	26	16,75	49, 51
4	17 ζ Caſſiopea	4	0	25	53,93	3, 262	52	49	N	6	28	29,01	48, 93
5	31 δ Andromeda	3	0	28	39,02	3, 161	29	45	N	7	9	45,31	47, 42
6	18 α Caſſiopea	3	0	29	14,40	3, 311	55	26	N	7	18	35,95	49, 66
7	16 β Cetus	2 3	0	33	31,83	3, 001	19	5	S	8	22	57,40	45, 01
8	24 η Caſſiopea	4	0	37	1.44	3, 389	56	46	N	9	15	21,64	50, 83
9	63 δ Piſces	4	0	38	19,08	3, 093	6	30	N	9	34	46,15	46, 39
10	27 γ Caſſiopea	3	0	44	44,75	3, 505	59	38	N	11	11	11,29	52, 58
11	71 ε Piſces	4	0	52	33,95	3, 103	6	49	N	13	8	29,20	46, 55
12	43 β Andromeda	2	0	58	34,23	3, 297	34	33	N	14	38	33,38	49, 46
13	33 ϑ Caſſiopea	4	0	59	0,22	3, 531	53	35	N	14	45	3,33	52, 96
14	86 ζ Piſces	4	1	3	16,99	3, 109	6	31	N	15	49	14,80	46, 63
15	37 δ Caſſiopea	3	1	12	50,58	3, 761	59	11	N	18	12	38,70	56, 42
16	98 μ Piſces	5	1	19	42,07	3, 108	5	7	N	19	55	31,07	46, 62
17	102 π Piſces	5	1	30	30,70	3, 164	11	7	N	22	37	40,56	47, 46
18	106 ν Piſces	4 5	1	31	1,77	3, 107	4	28	N	22	45	26,62	46, 61
19	110 ο Piſces	4 5	1	34	50,72	3, 144	8	9	N	23	42	40,84	47, 16
20	45 ε Caſſiopea	3	1	40	10,01	4, 155	62	41	N	25	2	30,13	62, 33
21	55 ζ Cetus	3	1	41	36,69	2, 953	11	20	S	25	24	10,33	44, 30
22	2 α Triang. North.	3 4	1	41	42,74	3, 379	28	36	N	25	25	41,15	50, 68
23	5 γ^1 Aries	4	1	42	34,52	3, 258	18	19	N	25	38	37,73	48, 87
24	6 β Aries	3	1	43	36,77	3, 277	19	50	N	25	54	11,48	49, 15
25	9 λ Aries	5	1	46	48,86	3, 315	22	37	N	26	42	12,83	49, 73
26	57 γ Andromeda	2	1	51	41,05	3, 615	41	22	N	27	55	15,76	54, 23
27	* preced. α ♈	.	1	50	26,15	. . .	. . . . .			27	36	32,25	. . .
28	13 α ARIES	2	1	55	55,27	3, 335	22	31	N	28	58	49,05	50 02
29	* ſequ. α ♈	.	1	59	38,13	. . .	. . . . .			29	54	31,95	. . .
30	22 ϑ^1 Aries	5 6	2	7	1,64	3, 308	18	58	N	31	45	24,55	49, 62

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Aſcenſion in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Aſcenſion in Equat. Part.	Annual Variation in R. A.
			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
31	68 ο Cetus (Varia.)	0 2	2 9 14,70	3, 019	3 54 S	32 18 40,50	45, 29
32	42 π Aries	6	2 38 9,29	3, 321	16 38 N	39 32 19,32	49, 81
33	43 σ Aries	6	2 40 28,09	3, 285	14 15 N	40 7 1,39	49, 28
34	82 δ Cetus	3	2 29 14,17	3, 060	0 33 S	37 18 32,54	45, 90
35	83 ε Cetus	3	2 29 53,42	2, 884	12 44 S	37 28 21,37	43, 27
36	86 γ Cetus	3	2 32 57,18	3, 102	2 23 N	38 14 17,76	46, 53
37	89 π Cetus	3	2 34 36,02	2, 849	14 43 S	38 39 0,29	42, 74
38	39 ♈ Lilius North.	4	2 35 57,70	3, 521	28 25 N	38 59 25,49	52, 81
39	41 ♈ Lilius South.	4	2 38 14,43	3, 489	26 26 N	39 33 36,49	52, 34
40	40 ρ² Aries	6	2 44 35,65	3, 344	17 31 N	41 8 54,72	50, 16
41	46 ρ³ Aries	5 6	2 45 9,35	3, 340	17 13 N	41 17 20,19	50, 10
42	3 η Eridanus	3	2 46 39,72	2, 917	9 42 S	41 39 55,78	43, 75
43	48 ι Aries	5	2 47 48,01	3, 401	20 32 N	41 57 1,80	51, 01
44	23 γ Perſeus	3	2 50 24,42	4, 250	52 43 N	42 36 6,25	63, 75
45	92 α CETUS (Me.)	2	2 51 50,07	3, 119	3 18 N	42 57 31,06	46, 66
46	* ſequ. α Cetus	.	2 51 54,61	. . .	. . . .	42 58 39,15	. . .
47	26 β Perſeus	2 3	2 55 12,07	3, 846	40 11 N	43 48 1,04	57, 69
48	57 δ Aries	4	3 0 12,71	3, 393	18 58 N	45 3 10,59	50, 89
49	58 ζ Aries	5	3 3 25,98	3, 422	20 18 N	45 51 29,77	51, 33
50	13 ζ Eridanus	3	3 6 7,48	2, 904	9 34 S	46 31 52,20	43, 56
51	61 τ¹ Aries	7	3 9 42,36	3, 433	20 25 N	47 25 35,39	51, 49
52	33 α Perſeus	2	3 10 6,85	4, 203	49 8 N	47 31 42,77	63, 05
53	63 τ² Aries	6	3 11 16,37	3, 428	20 1 N	47 49 5,48	51, 42
54	65 Aries	7	3 12 55,52	3, 430	20 5 N	48 13 52,74	51, 45
55	5 *f* Taurus	5	3 19 54,65	3, 289	12 15 N	49 57 39,78	49, 33
56	18 ε Eridanus	3 4	3 23 31,52	2, 883	10 9 S	50 52 52,84	43, 24
57	39 δ Perſeus	3	3 28 44,93	4, 203	47 8 N	52 11 13,91	63, 05
58	25 η Lucida Pleïad.	3	3 35 37,17	3, 535	23 29 N	53 54 17,56	53, 03
59	44 ζ Perſeus	3	3 41 35,20	3, 734	31 17 N	55 23 48,00	56, 01
60	45 ε Perſeus	3	3 44 29,19	3, 977	39 25 N	56 7 17,87	59, 66

Catalogue of the principal Fixed Stars to the beginning of the Year Eighteen Hundred.

N° of Star.	Name and Character of Star.	Magnitude.	Medium Right Aſcenſion in Time.	Annual Variation in R. A. and in Time.	Medium Declination.	Medium Right Aſcenſion in Equat. Part.	Annual Variation in R. A.
			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
61	34 γ Eridanus	2 3	3 48 42,25	2, 786	14 5 S	57 10 33,77	41, 79
62	37 *A* Taurus	5	3 52 53,46	3, 515	21 32 N	58 13 21,83	52, 72
63	54 γ Taurus	3	4 8 25,23	3, 387	15 8 N	62 6 18,48	50, 80
64	61 δ^1 Taurus	3 4	4 11 24,68	3, 432	17 4 N	62 51 10,26	51, 48
65	64 δ^2 Taurus	4	4 12 34,93	3, 431	16 58 N	63 8 43,89	51, 46
66	65 κ^1 Taurus	5	4 13 27,66	3, 545	21 50 N	63 21 54,93	53, 17
67	67 κ^2 Taurus	4 5	4 13 31,13	3, 543	21 44 N	63 22 47,02	53, 14
68	74 ε Taurus	3 4	4 16 56,98	3, 475	18 44 N	64 14 14,76	52, 12
69	77 ϑ^1 Taurus	5	4 17 9,30	3, 401	15 31 N	64 17 19,53	51, 02
70	78 ϑ^2 Taurus	5	4 17 19,53	3, 399	15 25 N	64 19 52,91	50, 99
71	✱ preced. α ♉	.	4 22 12,56	. . .	. . . .	65 33 8,40	. . .
72	87 ALDEBARAN.	1	4 24 27,29	3, 421	16 6 N	66 6 49,38	51, 31
73	✱ ſequ. α ♉	.	4 26 43,44	. . .	. . . .	66 40 51,60	. . .
74	91 σ^1 Taurus	6	4 27 44,78	3, 406	15 24 N	66 56 11,77	51, 09
75	52 υ^2 Eridanus	3 4	4 27 47,26	2, 329	30 59 S	66 56 48,83	34, 94
76	92 σ^2 Taurus	6	4 27 50,67	3, 409	15 31 N	66 57 40,07	51, 13
77	54 Eridanus	3 4	4 31 43,15	2, 615	20 4 S	67 55 47,21	39, 23
78	102 ι Taurus	4	4 51 9,38	3, 565	21 18 N	72 47 20,75	53, 47
79	67 β Eridanus	3	4 58 2,38	2, 948	5 21 S	74 30 35,74	44, 22
80	69 λ Eridanus	4	4 59 34,73	2, 863	9 1 S	74 53 40,95	42, 95
81	✱ preced. α Auriga	.	5 1 39,44	. . .	. . . .	75 24 51,60	. . .
82	13 CAPELLA	1	5 1 56,16	4, 414	45 47 N	75 29 2,40	66, 21
83	✱ ſequ. α Auriga	.	5 3 14,28	. . .	. . . .	75 48 34,20	. . .
84	✱ preced. β Orion	.	5 3 56,39	. . .	. . . .	75 59 5,85	. . .
85	19 RIGEL	1	5 4 55,54	2, 867	8 27 S	76 13 53,10	43, 01
86	✱ ſequ. β Orion	.	5 8 24,57	. . .	. . . .	77 6 8,55	. . .
87	120 β TAURUS	2	5 13 39,38	3, 778	28 26 N	78 24 50,70	56, 67
88	24 γ Orion	2	5 14 24,54	3, 209	6 9 N	78 36 8,16	48, 13
89	9 β Lepus	3 4	5 19 41,09	2, 565	20 56 S	79 55 16,40	38, 47
90	34 δ Orion	2	5 21 47,38	3, 057	0 28 S	80 26 53,69	45, 86

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
121	69 υ Gemini	4 5	7 23 34,54	3, 715	27 21 N	110 53 38,04	55, 72
122	✳ preced. α Can. mi.	.	7 26 40,27	. . .	. . . .	111 40 4,05	. . .
123	10 PROCYON	1 2	7 28 49,10	3, 137	5 44 N	112 12 16,50	47, 06
124	✳ ſequ. α Can. min.	.	7 30 27,12	. . .	. . .	112 36 46,80	. . .
125	78 POLLUX	2	7 33 3,18	3, 687	28 30 N	113 15 47,70	55, 31
126	✳ ſequ. β Gemini	.	7 35 28,78	. . .	. . . .	113 52 11,70	. . .
127	10 μ^2 Cancer	5	7 55 57,64	3, 545	22 9 N	118 59 24,55	53, 18
128	14 ψ^2 Cancer	4	7 58 23 25	3, 639	26 7 N	119 35 48,73	54, 58
129	17 β Cancer	3 4	8 5 39,37	3, 266	9 48 N	121 24 50,61	48, 99
130	31 ϑ Cancer	5 6	8 20 10,35	3, 441	18 46 N	125 2 35,31	51, 61
131	33 η Cancer	6 7	8 21 7,79	3, 491	21 6 N	125 16 56,87	52, 36
132	4 δ Hydra	4	8 27 3,04	3, 189	6 23 N	126 45 45,53	47, 83
133	43 γ Cancer	4	8 31 41,86	3, 499	22 10 N	127 55 27,85	52, 49
134	47 δ Cancer	4	8 33 18,11	3, 428	18 53 N	128 19 31,70	51, 42
135	11 ε Hydra	4	8 36 10,14	3, 199	7 8 N	129 2 32,03	47, 98
136	16 ζ Hydra	4 5	8 44 48,86	3, 187	6 42 N	131 12 12,84	47, 81
137	60 α^1 Cancer	4 5	8 44 59,39	3, 290	12 24 N	131 14 50,81	49, 35
138	65 α^2 Cancer	3 4	8 47 31,82	3, 292	12 37 N	131 52 57,26	49, 38
139	76 κ Cancer	4 5	8 56 54,33	3, 263	11 28 N	134 13 34,92	48, 95
140	66 ξ^1 Cancer	5 6	8 58 30,37	3, 472	22 51 N	134 27 35,48	52, 08
141	22 ϑ Hydra	4	9 3 54,80	3, 120	3 10 N	135 58 42,03	46, 80
142	1 κ Leo	4	9 12 58,32	3, 524	27 2 N	138 14 34,77	52, 86
143	30 ALPHARD	2	9 17 44,97	2, 935	7 48 S	139 26 14,55	44, 03
144	✳ ſequ. α Hydra	.	9 23 9,19	. . .	. . . .	140 47 17,85	. . .
145	5 ξ Leo	4	9 21 9,26	3, 253	12 11 N	140 17 18,97	48, 80
146	14 ο Leo	4	9 30 27,65	3, 224	10 48 N	142 36 54,82	48, 36
147	17 ε Leo	3	9 34 28,29	3, 434	24 41 N	143 37 4,31	51, 51
148	24 μ Leo	3	9 41 21,84	3, 457	26 57 N	145 20 27,54	51, 85
149	27 ν Leo	4	9 47 26,92	3, 243	13 24 N	146 51 43,76	48, 65
150	29 π Leo	4	9 49 37,99	3, 183	9 0 N	147 24 29,89	47, 75

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
151	30 η Leo	3 4	9 52 24,60	3, 289	17 44 N	149 6 9,04	49, 33
152	32 REGULUS	1	9 57 42,02	3, 204	12 56 N	149 25 30,30	48, 06
153	* ſequ. α Leo	.	10 4 28,58	. . .	. . . .	151 7 8,70	. . .
154	36 ζ Leo	3	10 5 32,34	3, 361	24 25 N	151 23 5,16	50, 42
155	41 γ^2 Leo	2 3	10 8 55,22	3, 306	20 51 N	152 13 48,23	49, 60
156	34 μ Urſa major	3	10 10 21,35	3, 635	42 30 N	152 35 23,32	54, 52
157	47 ρ Leo	4	10 22 15,77	3, 170	10 20 N	155 33 56,49	47, 55
158	48 β Urſa major	2	10 49 39,53	3, 709	57 27 N	162 24 52,93	55, 63
159	7 α Crater	4	10 50 4 55	2, 943	17 14 S	162 31 8,25	44, 14
160	50 α Urſa major	1 2	10 51 15,84	3, 847	62 50 N	162 48 57,61	57, 70
161	11 β Crater	3 4	11 1 50,06	2, 933	31 44 S	165 27 30,97	44, 02
162	68 δ Leo	2 3	11 3 26,39	3, 199	21 37 N	165 51 35,91	47, 98
163	70 θ Leo	3	11 3 44,23	3, 165	16 31 N	165 56 3,49	47, 48
164	13 λ Crater	5 6	11 13 28,15	2, 981	17 17 S	168 22 2,21	44, 72
165	78 ι Leo	4	11 13 28,32	3, 125	11 38 N	168 22 4,85	46, 87
166	84 τ Leo	4	11 17 39,49	3, 085	3 57 N	169 24 52,34	46, 28
167	91 υ Leo	4	11 26 42,82	3, 069	0 17 N	171 40 42,29	46, 04
168	3 ν Virgo	5	11 35 34,11	3, 087	7 39 N	173 53 51,70	46, 31
169	* preced. β Leo	.	11 38 19,46	. . .	. . . .	174 34 51,90	. . .
170	94 DENEBOLA	1 2	11 38 50,49	3, 062	15 41 N	174 42 37,35	45, 93
171	5 β Virgo	3	11 40 16,38	3, 122	2 54 N	175 4 5,70	46, 83
172	64 γ Urſa major	2	11 43 14,22	3, 212	54 48 N	175 48 33,33	48, 18
173	1 α Corvus	4	11 58 6,94	3, 062	23 37 S	179 31 44,10	45, 93
174	2 ε Corvus	4	11 59 51,63	3, 067	21 30 S	179 57 54,47	46, 00
175	69 δ Urſa major	3	12 5 27,23	3, 021	58 9 N	181 21 48,42	45, 32
176	4 γ Corvus	3	12 5 32,31	3, 077	16 26 S	181 23 4,58	46, 16
177	15 η Virgo	3	12 9 40,74	3, 067	0 27 N	182 25 11,13	46, 01
178	9 β Corvus	3	12 23 54,39	3, 124	22 17 S	185 58 35,92	46, 86
179	5 κ Draco	3	12 24 47,65	2, 661	70 53 N	186 11 54,72	39, 91
180	29 γ^1 Virgo	3	12 31 33,85	3, 069	0 21 S	187 53 27,72	46, 03

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			h ′ ″ 1/100	″ 1/1000	° ′ Nor. Sou.	° ′ ″ 1/100	″ 1/100
				+			+
241	21 ANTARES	1	16 17 9,69	3, 645	25 58 s	244 17 25,35	54, 68
242	* α Scorpio	.	16 19 6,66	. . .	. . . .	244 46 39,90	. . .
243	8 φ Ophiuchos	4 5	16 19 43,03	3, 418	16 10 s	244 55 45,42	51, 27
244	14 η Draco	3 4	16 21 18,33	0, 785	61 58 N	245 19 34,92	11, 78
245	27 β Hercules	3	16 21 37,87	2, 579	21 56 N	245 24 28,08	38, 68
246	23 τ Scorpio	4	16 23 26,96	3, 709	27 47 s	245 51 44,36	55, 64
247	13 ζ Ophiuchos	2 3	16 26 9,55	3, 287	10 9 s	246 32 23,24	49, 30
248	40 ζ Hercules	3 4	16 33 45,64	2, 292	32 1 N	248 26 24,67	34, 38
249	44 η Hercules	3 4	16 36 3,14	2, 046	39 19 N	249 0 47,15	30, 69
250	58 ε Hercules	3	16 52 38,68	2, 292	31 16 N	253 9 40,16	34, 38
251	35 η Ophiuchos	2 3	16 58 55,15	3, 424	15 28 s	254 43 47,26	51, 36
252	* preced. α Hercules	.	17 5 12,70	. . .	. . .	256 18 10,50	. . .
253	64 α HERCULES	2 3	17 5 31,76	2, 726	14 38 N	256 22 56,40	40, 89
254	65 δ Hercules	3 4	17 6 49,41	2, 459	25 5 N	256 42 21,17	36, 88
255	42 θ Ophiuchos	3	17 9 44,25	3, 669	24 47 s	257 26 3,68	55, 04
256	35 λ Scorpio	3	17 20 2,64	4, 057	36 57 s	260 0 39,58	60, 85
257	* preced. α Ophiu.	.	17 24 45,90	. . .	. . . .	261 11 28,50	. . .
258	55 α OPHIUCHOS	2	17 25 38,97	2, 768	12 43 N	261 24 44,55	41, 52
259	* ſequ. α Ophiuchos	.	17 29 11,02	. . .	. . . .	262 17 45,32	. . .
260	23 β Draco	3	17 25 55,99	1, 348	52 27 N	261 28 59,82	20, 22
261	60 β Ophiuchos	3	17 33 35,77	2, 959	4 40 N	263 23 56,54	44, 39
262	62 γ Ophiuchos	3	17 37 52,04	3, 003	2 48 N	264 28 0,56	45, 05
263	57 ζ Serpens	3 4	17 49 54,59	3, 153	3 40 s	267 28 38,87	47, 30
264	67 ο Oph. v. Taur. Poniatowſky	4	17 50 37,47	2, 999	2 57 N	267 39 21,99	44, 99
265	33 γ Draco	2 3	17 51 57,79	1, 389	51 31 N	267 59 26,85	20, 83
266	10 γ Sagittarius	3 4	17 52 58,05	3, 851	30 25 s	268 14 30,76	57, 77
267	. b Taur. Poniat.	.	18 0 41,10	2, 993	3 19 N	270 10 16,50	44, 90
268	13 μ^1 Sagittarius	4	18 1 48,37	3, 584	21 6 s	270 27 5,63	53, 76
269	15 μ^2 Sagittarius	4 6	18 3 16,90	3, 575	20 46 s	270 49 13,57	53, 62
270	20 ε Sagittarius	2 3	18 10 53,67	3, 984	34 28 s	272 43 25,11	59, 76

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
271	22 λ Sagittarius	4	18 15 37,66	3, 705	25 31 S	273 54 24,92	55, 57
272	* preced. α Lyra	.	18 28 40,12	. . .	. . . .	277 10 1,88	. . .
273	3 WEGA	1	18 30 9,89	1, 994	38 36 N	277 32 28,35	29, 91
274	* ſequ. α Lyra	.	18 31 40,00	. . .	. . . .	277 54 50,00	. . .
275	27 φ Sagittarius	3 4	18 33 9,39	3, 747	27 11 S	278 17 20,84	56, 21
276	4 ε Lyra	5	18 37 42,87	1, 983	39 28 N	279 25 43,03	29, 74
277	32 ν^1 Sagittarius	4 5	18 42 5,41	3, 625	22 59 S	280 31 21,22	54, 38
278	10 β Lyra	3	18 42 41,86	2, 211	33 9 N	280 40 27,89	33, 16
279	34 σ Sagittarius	3	18 42 51,40	3, 724	26 32 S	280 42 50,99	55, 86
280	35 ν^2 Sagittarius	4 5	18 43 1,13	3, 623	22 54 S	280 45 16,99	54, 35
281	63 ϑ Serpens Dup.	3	18 46 16,82 18,32	2, 977	3 57 N	281 34 12,35 34,84	44, 66
282	12 δ Lyra	3 4	18 47 31,16	2, 095	36 39 N	281 52 47,43	31, 42
283	47 ο Draco	4	18 48 14,15	0, 880	59 9 N	282 3 32,20	13, 21
284	14 γ Lyra	3	18 51 27,04	2, 241	32 26 N	282 51 45,55	33, 61
285	39 ο Sagittarius	4	18 52 41,18	3, 595	22 1 S	283 10 17,72	53, 92
286	40 τ Sagittarius	4	18 54 26,45	3, 758	27 57 S	283 36 36,82	56, 37
287	16 λ Antinous	3 4	18 55 38,10	3, 186	5 10 S	283 54 31,55	47, 79
288	17 ζ Aquila	3	18 56 12,69	2, 755	13 35 N	284 3 10,37	41, 33
289	41 π Sagittarius	3 4	18 57 51,37	3, 574	21 20 S	284 27 50,57	53, 61
290	42 ψ Sagittarius	4 5	19 3 15,27	3, 685	25 35 S	285 48 49,04	55, 27
291	43 *d* Sagittarius	4 6	19 5 55,86	3, 517	19 18 S	286 28 57,90	52, 76
292	57 δ Draco	3	19 12 27,95	0, 033	67 19 N	288 6 59,21	0, 49
293	1 κ Cygnus	4	19 12 28,28	1, 383	52 58 N	288 7 4,19	20, 73
294	30 δ Aquila	3	19 15 24,12	3, 008	2 44 N	288 51 1,79	45, 12
295	6 β Cygnus	3	19 22 38,53	2, 415	27 33 N	290 39 37,97	36, 23
296	10 ι Cygnus	4 6	19 24 39,61	1, 511	51 19 N	291 9 54,19	22, 67
297	41 ι Antinous	3 4	19 26 22,16	3, 106	1 43 S	291 35 32,37	46, 59
298	13 ϑ Cygnus	4	19 31 5,16	1, 645	49 46 N	292 46 17,40	24, 68
299	5 α Sagitta	4	19 31 9,25	2, 678	17 34 N	292 47 18,74	40, 17
300	56 *f* Sagittarius	6	19 34 41,43	3, 520	20 14 S	293 40 21,39	52, 80

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				+			+
301	* preced. γ Aquila	.	19 35 12,50	. . .	. . . .	293 48 7,50	. . .
302	50 γ AQUILA	3	19 36 44,50	2, 837	10 8 N	294 11 7,50	42, 59
303	* ſequ. γ Aquila	.	19 39 0,81	. . .	. . . .	294 45 12,16	. . .
304	18 δ Cygnus	3	19 38 43,09	1, 869	44 39 N	294 40 46,34	28, 02
305	* preced. α Aquila	.	19 38 35,87	. . .	. . . .	294 38 58,05	. . .
306	53 ATAIR	1 2	19 41 1,02	2, 918	8 21 N	295 15 15,30	43, 78
307	* ſequ. α Aquila	.	19 42 52,37	. . .	. . . .	295 43 5,55	. . .
308	55 η Antinous	3 4	19 42 17,14	3, 058	0 30 N	295 34 17,08	45, 87
309	59 b Sagittarius	4 5	19 44 39,56	3, 699	27 41 S	296 9 53,46	55, 48
310	60 β AQUILA	3 4	19 45 28,97	2, 939	5 55 N	296 22 14,55	44, 08
311	65 ϑ Aquila	3	20 0 58,52	3, 097	1 24 S	300 14 37,75	46, 45
312	5 α^1 CAPRICOR.	3 4	20 6 32,79	3, 330	13 7 S	301 38 11,88	49, 95
313	* preced. α^2 Capricor.	.	20 5 17,48	. . .	. . . .	301 19 22,20	. . .
314	6 α^2 CAPRICOR.	3	20 6 56,48	3, 331	13 9 S	301 44 7,20	49, 96
315	* ſequ. α^2 Capricor.	.	20 9 33,32	. . .	. . . .	302 23 19,80	. . .
316	prec. β Capr. N. 827 Mayer	.	20 9 31,35	3, 380	15 24 S	302 22 50,19	50, 70
317	8 ν Capricornus	6	20 9 33,69	3, 337	13 23 S	302 23 25,39	50, 06
318	9 β Capricornus	3	20 9 45,50	3, 380	15 24 S	302 26 22,54	50, 70
319	37 γ Cygnus	3	20 15 2,63	2, 148	39 38 N	303 45 39,39	32, 22
320	11 ρ Capricornus	6	20 17 26,45	3, 438	18 28 S	304 21 36,72	51, 57
321	4 ζ Delphinus	4 5	20 25 57,50	2, 801	14 0 N	306 29 22,44	42, 01
322	6 β Delphinus	3	20 28 10,32	2, 804	13 55 N	307 2 34,74	42, 06
323	9 α Delphinus	. 3	20 30 20,76	2, 780	15 13 N	307 35 11,37	41, 70
324	50 DENEB.	1 2	20 34 36,68	2, 034	44 34 N	308 39 10,20	30, 51
325	* ſequ. α Cygnus	.	20 40 28,55	. . .	. . . .	310 7 8,25	. . .
326	2 ε Aquarius	4 5	20 36 50,38	3, 255	10 13 S	309 12 35.72	48, 83
327	* preced. γ Delphi.	.	20 37 21,94	. . .	. . . .	309 20 29,08	. . .
328	12 γ Delphinus	3	20 37 22,96	2, 783	15 25 N	309 20 44,34	41, 75
329	53 ε Cygnus	3	20 38 6,70	2, 393	33 13 N	309 31 40,56	35, 89
330	6 μ Aquarius	4 5	20 41 51,17	3, 243	9 43 S	310 27 47,61	48, 65

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			h ′ ″ $\frac{1}{100}$	″ $\frac{1}{1000}$	° ′ Nor. Sou.	° ′ ″ $\frac{1}{100}$	″ $\frac{1}{100}$
				+			+
331	7 Aquarius	6	20 46 4,59	3, 255	10 28 S	311 31 8,80	48, 82
332	23 ϑ Capricornus	5 4	20 54 39,75	3, 384	18 1 S	313 39 56,25	50, 76
333	13 ν Aquarius	5	20 58 41,24	3, 274	12 10 S	314 40 18,64	49, 11
334	8 α Equuleus	4	21 5 48,78	2, 997	4 26 N	316 27 11,73	44, 96
335	32 ι Capricornus	5	21 11 5,67	3, 355	17 41 S	317 46 25,00	50, 33
336	4 β Equuleus	6	21 12 57,71	2, 981	5 58 N	318 14 25,62	44, 72
337	18 Aquarius	6	21 13 14,77	3, 286	13 44 S	318 18 41,53	49, 29
338	5 α Cepheus	3	21 13 46,85	1, 427	61 45 N	318 26 42,69	21, 40
339	22 β Aquarius	3	21 21 1,12	3, 165	6 27 S	320 15 16,74	47, 48
340	39 ε Capricornus	4	21 25 52,29	3, 379	20 21 S	321 28 4,34	50, 68
341	8 β Cepheus	3	21 26 1,18	0, 821	69 41 N	321 30 17,76	12, 32
342	40 γ Capricornus	3 4	21 28 59,14	3, 329	17 33 S	322 14 47,15	49, 93
343	43 κ Capricornus	5	21 31 27,98	3, 360	19 46 S	322 51 59,74	50, 40
344	8 ε Pegaſus	3	21 34 21,53	2, 943	8 58 N	323 35 22,99	44, 15
345	80 π^1 Cygnus	4	21 34 59,63	2, 116	50 17 N	323 44 54,38	31, 74
346	49 δ Capricornus	3	21 35 58,68	3, 310	17 1 S	323 59 40,25	49, 65
347	* preced. α Aquarius	.	21 55 8,21	. . . .	. . . .	328 47 3,15	. . .
348	34 α AQUARIUS	3	21 55 29,75	3, 067	1 17 S	328 52 26,25	46, 00
349	48 γ Aquarius	3	22 11 18,89	3, 094	2 23 S	332 49 43,29	46, 41
350	52 π Aquarius	4 5	22 15 4,00	3, 065	0 22 N	333 45 59,98	45, 97
351	55 ζ Aquarius	4	22 18 31,68	3, 079	1 2 S	334 37 55,26	46, 18
352	57 σ Aquarius	5	22 20 2,99	3, 186	11 42 S	335 0 44 84	47, 79
353	7 Lacerta	4	22 23 7,61	2, 431	49 16 N	335 46 54,14	36, 46
354	62 η Aquarius	4	22 25 4,59	3, 079	1 9 S	336 16 8,78	46, 19
355	63 κ Aquarius	5	22 27 23,38	3, 117	5 14 S	336 50 50,67	46, 76
356	42 ζ Pegaſus	3	22 31 29,06	2, 981	9 48 N	337 52 15,89	44, 72
357	44 η Pegaſus	3	22 33 37,87	2, 792	29 11 N	338 24 27,91	41, 88
358	69 τ^1 Aquarius	5	22 37 4,70	3, 197	15 7 S	339 16 10,57	47, 96
359	71 τ^2 Aquarius	5 6	22 38 59,29	3, 190	14 39 S	339 44 49,41	47, 85
360	73 λ Aquarius	4	22 42 10,52	3, 137	8 38 S	340 32 37,87	47, 05

and ſays, that, as he approached it, he beheld, from the top of a very high mountain, an immenſe valley, adorned with agreeable hills, variegated in an infinite number of ſhapes, and extending in an undulating manner as far as the ſea; whilſt enamelled meads, and the moſt beautiful paſtures, ſtill added to the magnificent ſcene. It abounds with ſmall rivulets, which, flowing down from the mountains, run into the ſea through an hundred different channels. The water of theſe rivulets has the colour of Madeira wine, and a ferruginous taſte; but our traveller did not examine whether this taſte and colour proceed from their flowing through ſome mine in their paſſage, or from the roots and leaves of trees which they carry along with them.

The whole of Auteniqua, from the chain of mountains which divides it from the country of that race of Hottentots called *Gonaquas* to the ſea, is inhabited by ſeveral planters, who rear a number of cattle, make butter, cut down timber, and collect honey; all of which they tranſport to the Cape: but it appears that they make not the moſt of their ſituation. "Can it be believed (ſays M. Vaillant), that the directors of the Company, for their own uſe, ſhould order ſhips to be ſent every year from Amſterdam, loaded with planks and boards of every kind, whilſt in this country there are immenſe foreſts, and the moſt beautiful trees in the world? This abſurdity, however, is not at all aſtoniſhing. The Company gratuitouſly furniſhes the governor and all the officers with whatever wood they have occaſion for; and it is delivered to them at their houſes without any expence. The governor therefore has no *perſonal* intereſt to extend his views to this part of the adminiſtration, and to aboliſh an abuſe ſo prejudicial to the colony."

But the coloniſts themſelves muſt be a very indolent and ſtupid kind of people; ſince, if our traveller deſerves credit, they neglect advantages with which the perſonal intereſt of the governor cannot poſſibly interfere. "I was filled with indignation (ſays M. Vaillant) to ſee people, who have wood within their reach, employ it in commerce, and not have the courage to build for themſelves habitable houſes. They live in wretched hovels, conſtructed of wicker-work, daubed over with clay; the ſkin of a buffalo, fixed at the four corners to as many ſtakes, ſerves them for a bed; and the door, which is at the ſame time a window, is ſhut by a mat; while two or three mutilated chairs, a few pieces of plank, a kind of table, and a pitiful box of two feet ſquare, form all the furniture of theſe colonial habitations. Thus is the picture of the moſt profound miſery contraſted with the charms of this terreſtial paradiſe; for the beauties of theſe regions extend even beyond Auteniqua. The people, however, though their houſes be bad, live well. They have game and ſalt-water fiſh in abundance; and enjoy excluſively, over all the other cantons of theſe colonies, the advantage of having, for the whole year without interruption, vegetables of every kind in their gardens. For this they are indebted to the excellence of the ſoil, and to its being naturally watered by ſmall ſtreams, which croſs each other in a thouſand different directions, and, as one may ſay, lay the four ſeaſons under contribution to fertilize Auteniqua. Theſe ſtreams, which frequently overflow their banks, but never dry up, proceed from a cauſe well known; the high mountains towards the eaſt, which are covered with foreſts, ſtop the clouds and the fogs carried from the ſea, and this occaſions very abundant rains."

In theſe mountainous regions, which, as well as the plain, our author comprehends under the denomination of *Auteniqua*, there are multitudes of elephants, buffaloes, panthers, hyenas, and antelopes of every ſpecies; and all theſe animals are hunted and killed by the natives, as well for food as for the protection of their flocks and herds from ſuch of them as are beaſts of prey. Our author has eaten the fleſh of every one of them except the hyena; and declares, that the foot of an elephant, baked after the Hottentot manner, is one of the moſt delicious morſels that he ever taſted. He gives directions for hunting them all; but warns his readers from attacking elephants when he finds them in droves, for then, he ſays, they are invincible. He even thinks it exceedingly dangerous for one man, however well armed, to attack a ſingle elephant in the plain. The buffalo he deſcribes, contrary to moſt other travellers, as a timid animal, which never reſiſts till his ſituation becomes deſperate; and he thinks that there would be no difficulty in training him, if caught when a calf, to the yoke like the bullocks of Europe.

The kites and vultures of this country, our traveller repreſents as in the higheſt degree voracious and fierce, inſomuch that it is hardly poſſible to fright them from their prey. He had on one occaſion killed two buffaloes, which he ordered to be cut into very ſmall pieces, that they might be more eaſily ſalted, and expoſed afterwards to the air and the ſun. His waggons, as well as the buſhes and trees which ſurrounded him and his people, were loaded with the bloody fragments of theſe two animals, and they had begun their operation of ſalting; but on a ſudden, while they were not expecting it, they found themſelves attacked by flights of kites and vultures, which, without exhibiting the leaſt ſymptoms of fear, perched in the midſt of them. The kites were above all the moſt impudent. They ſeized upon the morſels of fleſh, and even contended furiouſly with his people. "When they had each carried away (ſays he) a pretty large piece, they retired to ſome branch, at the diſtance of ten paces from us, and devoured it before our eyes. Though we fired our fuſees they were not frightened, but returned inceſſantly to the charge; ſo that finding our powder waſted in vain, we reſolved to keep them off with large poles until our proviſions ſhould be quite dry. This manœuvre, which for a long time harraſſed my people, did not prevent us from being plundered without mercy; but had we not employed it, nothing would have remained to us of our two buffaloes."

This battle with the kites took place on the confines of the Dutch ſettlements; but when M. Vaillant had with difficulty paſſed over the mountains which bound them, the proſpects became more magnificent, the ſoil ſeemed to be more fruitful and rich, nature appeared to be more majeſtic and grand, and the lofty mountains preſented on all ſides more charming and delightful points of view than any that he had ever before met with. Theſe ſcenes, contraſted with the dry and parched fields of the Cape, made him exclaim, he ſays, in ecſtacy, "What! ſhall theſe ſuperb regions be eternally inhabited by tygers and lions? What ſpeculator, with the ſordid view only of eſtabliſhing a kind of centre for commerce, could have preferred the ſtormy Table Bay to the numberleſs roads and commodious harbours which are to be found on the eaſtern coaſts of Africa? Thus (continues he) was I reflecting within myſelf, whilſt I was climbing the mountain, and forming vain wiſhes for the conqueſt of this beautiful country, which the indolent policy of the European nations will perhaps never gratify."

If his deſcription of its beauties and fertility be not greatly exaggerated, it is indeed wonderful that either the Dutch or ſome other maritime power of Europe has not long ago taken poſſeſſion of it. After he had paſſed the mountain, one could not, he ſays, chooſe a more agreeable or advantageous ſpot than that upon which he then was for eſtabliſhing a thriving colony. The ſea advances through an opening of about a thouſand paces in breadth, and penetrates into the country to the diſtance of more than two leagues and a half. The baſon which it forms is more than a league in extent (he does not ſay whether in breadth or in circumference); and the whole coaſt, both on the right and the left, is bordered with rocks, which intercept all communication with it. The land is watered by limpid and refreſhing ſtreams, which flow down on all ſides from the eaſtern mountains; and theſe mountains, crowned with majeſtic woods, extending as far as the baſon, and winding round it with a number of ſinuoſities, exhibit a hundred groves, which are naturally variegated, and each more agreeable than another.

The author proceeding forwards about two days journey, arrived at a bay known to navigators by the name of the Bay of *Agoa*, but called by the coloniſts *Blettenberg's* Bay, from its having been viſited ſome time before by a Governor Blettenberg, who ordered his name, together with the year and day of his arrival, to be engraven on a ſtone column. This bay is a little beyond the limits of the country called Auteniqua; but it is not foreign from the purpoſe of this article to inſert in this place our traveller's account of it, and of the country around it.

The bay itſelf, he ſays, is very ſpacious, and has a ſufficient depth of water for the largeſt veſſels. The anchoring ground is ſure, and boats can ſail to a beautiful part of the ſhore, which is not confined by the rocks, as they are all there detached from one another. By advancing a league along the coaſt, the crews would arrive at the mouth of a conſiderable river called the *Queur-Boom*, where they would find water. Refreſhments might be procured from the inhabitants of the environs; and the bay would ſupply them with excellent fiſh, with which it abounds.

This bay is one of thoſe places where government might eſtabliſh warehouſes and repoſitories for timber; and it is for this reaſon that we have introduced it to notice in this article. The foreſts around it, ſays M. Vaillant, are everywhere magnificent, and the trees could be more eaſily cut down than anywhere elſe; for it is not to ſteep mountains that one muſt go for wood, as at Auteniqua; it is here ready at hand; and during the fine monſoon might be tranſported to the Cape with little trouble and no riſk. The inexhauſtible and fertile lands in the neighbourhood of the bay, if once cultivated, would produce abundant crops, and draw together a great number of intelligent planters, on account of the ready communication which they would have with the Cape. In a word, the Company, continues he, have nothing to do ſo much for their own intereſt as to form here a proper eſtabliſhment. To the general profits of ſuch an inſtitution, would be added thoſe of individuals, which could not fail to be of great importance. They might, for example, cut down a certain tree called *ſtinking wood*, and export it to Europe, where it would undoubtedly be ſoon preferred to mahogany and every other kind of wood employed by cabinet makers.

The Hottentots, who in ſcattered *kraals* inhabit this delightful country, our author deſcribes as a faithful, gentle, and rather timid race. He affirms, that they have no religious impreſſions whatever, nor any notion of ſuperior powers who govern the world. But this, if not a wilful falſehood dictated by the philoſophy of France, is probably a miſtake ariſing from his ſcanty knowledge of their language, and total ignorance of the meaning of their religious ceremonies. His great maſter, as well as the maſter of his ſect, *Lucretius*, might have taught him, that fear, if not a better principle, will generate the notion of ſuperior beings in the minds of ſavages; and from fear, by his own account, the inhabitants of Auteniqua are far from being free. He likewiſe affirms, and ſeems to conſider it as much to their credit, that this race of gentle beings, ſo far from being a prey to the paſſion of jealouſy (as other travellers have repreſented the Hottentots in general), are ſo obliging, as to lend their wives to travellers who viſit them, and that they actually accommodated his Hottentots in this way. Auteniqua, as laid down in M. Vaillant's map, lies between 33° 30 and 34° 50′ of ſouth latitude, and between 20° and 23° 40′ of eaſt longitude; and his rout through the country was from ſouth-weſt to north-eaſt, or nearly ſo.

AUTOMATON. Under this title and that of ANDROIDES full credit was allowed in the *Encyclopædia* to the ſtory of M. de Kempell's mechanical *cheſs-player*, and a detail at ſome length was given of the feats of that figure, as well as of ſome other ſurpriſing *automata*. No man more readily admits the powers of the ſkilful mechanician than the writer of this ſhort article; but having many years ago detected the impoſition which was practiſed on the public in ſome parts of Scotland by a circumferaneous mountebank, who exhibited a figure apparently capable of writing a certain number of words, he has ever ſince ſuſpected impoſture in all automata which appear to have the power of varying their motions according to circumſtances. With reſpect to the *cheſs-player*, there is now ſufficient evidence that his ſuſpicions were well founded.

In the deſcription of this figure (*Encycl.* Vol. I. p. 787.), " it is ſaid, that the automaton could not play unleſs M. de Kempell or his ſubſtitute was near it to direct its moves. A ſmall box during the game was frequently conſulted by the exhibiter; and herein conſiſted the ſecret, which he ſaid he could in a moment communicate." The ſecret was indeed ſimple: " A well taught boy, very thin and ſmall of his age, was concealed in this box almoſt immediately under the cheſs-board, and agitated the whole machine." This we learn from Thomas Collinſon, Eſq. who was let into the ſecret at Dreſden by a gentleman of rank and talents, named *Joſeph Freidrick Freyhere*, by whom the *vitality* and *ſoul* of the cheſs-playing figure had ſome time before been completely diſcovered. Mr Collinſon, finding that Dr Hutton had given the ſame credit with us to the reality of mechanical cheſs-playing, undeceived his friend, by communicating the diſcovery of Freyhere in a letter, which the Doctor has with great propriety publiſhed in the *Addenda* to his Mathematical Dictionary. Mr Collinſon adds, and we doubt not with truth, that, "even after this abatement of its being ſtrictly an automaton, much ingenuity remains to the contriver." This was in ſome degree true of the mechaniſm of the writing figure, of which the compiler of this article detected the bungling impoſture of the two exhibiters. The figure itſelf, with all the principles of its motion, was very ingeniouſly conſtructed; but the two men who exhibited it were ignorant and aukward, and could not conceal from a ſcrutinizing eye, that the automaton wrote ſometimes well and ſometimes ill, and never wrote at all when they were both preſent to the company. It was by inſiſting upon ſeeing them both together, and threatening to expoſe the cheat to the whole town, that the preſent writer prevailed upon him who appeared to be the principal exhibiter, to confeſs in private that his companion was concealed behind a ſcreen, and to ſhow how, from thence, he directed the movements of the figure.

CONJUGATE AXIS, or *Second Axis*, in the ellipſe and hyperbola, is the diameter paſſing through the centre, and perpendicular to the tranſverſe axis; and is the ſhorteſt of all the conjugate diameters.

Tranſverſe Axis, in the ellipſe and hyperbola, is the diameter paſſing through the two foci and the two principal vertices of the figure. In the hyperbola it is the ſhorteſt diameter, but in the ellipſe it is the longeſt.

B.

BAAL's *River* and *Bay*, in Weſt Greenland, lie between Bear Sound on the S. E. and Delft's Point on the N. W. and oppoſite the mouth of Hudſon's Strait.—*Morſe*.

BABAHOYO, a village and cuſtom houſe on Guayaquil River, in Peru, being the landing place from the city of Guayaquil. Here the merchandize from Peru and Terra Firma, and their reſpective provinces, are landed.—*ib.*

BABOPAS, a town in the interior parts of New Albion, eaſtward of the long range of mountains which extend northward from the head of the peninſula of California. N. lat. 37. 45. W. long. 114. 25. —*ib.*

BAFFIN's *Bay*, is the largeſt and moſt northern gulf, or bay, that has yet been diſcovered in N. America; and lies between the 70th and 80th degrees of N. lat. It opens into the Atlantic ocean through Baffin's and Davis's ſtraits, between Cape Chidley on the Labrador coaſt, and Cape Farewell on that of Weſt Greenland; both of which are in about the 60th degree of N. lat. It abounds with whales; and on the S. W. ſide of Davis's ſtraits has a communication with Hudſon's Bay, through a cluſter of iſlands. It was diſcovered by the navigator whoſe name it bears, in the year 1662. Some maps ſhew a communication with Hudſon's Bay, in the 70th degree of N. lat. and in the 70th of W. long.—*ib.*

BAHAMA *Iſlands*, (See Encycl.) The firſt diſcovery of the New World, by Columbus, began October 11, 1492, at Guanahani, or Cats Iſland, one of the Bahamas. They were then full of people; who were ſimple, mild and lived happy in the midſt of plenty. Theſe unfortunate people were tranſported to the mines of St Domingo, after the cruel Spaniards had exterminated the numerous inhabitants of that large iſland; 14 years after the diſcovery of theſe iſlands, not one perſon remained in any of the Bahamas. At this time Charles II. granted the Bahamas to the proprietors of Carolina. They ſent ſeveral governors, and built the town of Naſſau, which is now the ſeat of government in the Iſland of Providence. The iſland of Providence afterwards became an harbour for pirates, who, for a long time, infeſted the American navigation. In 1718, Capt. Woods Rogers was ſent out to diſlodge the pirates, and form a ſettlement. This the captain effected; and the iſlands have been improving ſince by a ſlow progreſs. In time of war, the people gain conſiderably by the prizes condemned there; and in the courſe of the preſent war between Great-Britain and France, numbers of American veſſels, carrying proviſions and ſtores to French ports, have been carried in and condemned; and at all times they profit by the wrecks which are frequent in this labyrinth of rocks and ſhoals. The Spaniards and Americans captured theſe iſlands during the laſt war; but they were retaken April 7, 1783. The Bahamas are ſaid to be 500 in number; ſome of them only rocks, others very low and narrow, or little ſpots of land on a level with the water's edge; but 12 of them are large and fertile, ſome indeed rocky and barren. Five of them only are inhabited, viz. *Providence*, *Harbor*, *Eleuthera*, *Cat*, and *Exuma*; *Turk*'s iſlands have about 500 men in the ſalt ſeaſon, but at other times half of them return to Bermuda.

The principal iſland which has given its name to the whole cluſter is *Great Bahama*, in the *Northern Bank*, called the *Little Bank of Bahama*, whoſe ſituation is E. and W. about 20 leagues from the coaſt of Florida. At a little diſtance to the E. is *Lucayoneque*, of nearly the ſame ſize, whoſe ſituation is N. and S. To the N. of both is *Lucayo*, which lies E. and W. A channel occaſion; but he went home, comforting himſelf with the belief that he ſhould now have no farther trouble from Madam Godſchuſky or her girl. He chanced, however, to be miſtaken. The magiſtrate Bel had ſome how been made acquainted with this nefarious tranſaction, and brought it into court on the day that our hero was to make ſome very reverend appearance at church. The caſe of Bahrdt was now hopeleſs; for after ſome unſucceſsful attempts of his poor father to ſave him, he was obliged to give in his gown and band, and to quit Leipſig.

To a parent the public diſgrace of a child is one of the ſevereſt calamities to which human nature is liable; but for this calamity the father of Bahrdt muſt have been long prepared, as his ſon appears to have been remarkably undutiful. Of this we have one memorable inſtance recorded by himſelf. His father, he ſays, was ſevere, and his own temperament haſty, ſo that he ſometimes forgot himſelf. "One day (continues he) I laid a loaded piſtol on the table, and told him that he ſhould meet with that if he went on ſo; but I was then only SEVENTEEN!"

On his being obliged to leave the place of his nativity, the friends of Bahrdt, and in particular Semler, an eminent theological writer, who had formed a very favourable opinion of his talents, were aſſiduous in their endeavours to procure an eſtabliſhment for him elſewhere; but his high opinion of himſelf, his impetuous and precipitant temper, and that ſatirical habit which he had ſo freely indulged in his outſet in life, made their endeavours long ineffectual. At laſt he got a profeſſorſhip at Erlangen, then at Erfurth, and in 1771 at Gieſſen. But in each of theſe places he was no ſooner ſettled than he got into diſputes with his colleagues and with the eſtabliſhed church; for he was a ſtrenuous partizan of the innovations then attempted to be made in the doctrines of Chriſtianity. In his publications, which were generally anonymous, he did not truſt to rational diſcuſſion alone, but had recourſe to ridicule and perſonal anecdotes, and indulged in the moſt cutting ſarcaſms and groſs ſcurrility.

His love for convivial company continuing, his income was inſufficient for the craving demand. Finding therefore that anecdote and ſlander always procured readers, and poſſeſſing a wonderful activity and facility in writing, he never ceaſed from publiſhing lampoons and ſatires, in which he ſpared neither friends nor foes. But it was impoſſible to prevent theſe publications from being traced to their author; and his avowed theological writings being ſuch as could not be ſuffered in a profeſſor of divinity, the hoſt of enemies which he had been at ſo much pains to raiſe againſt himſelf, were furniſhed with ſufficient grounds for ſubjecting his conduct to legal cognizance; even the very ſtudents at Gieſſen were ſhocked at ſome of his liberties.

The conſequence of all this was, that, after much wrangling in the church judicatories, he was juſt about to be diſmiſſed from his profeſſorſhip, when he got an invitation to Marſchlins in Switzerland to ſuperintend an academy.

To Marſchlins he went about the year 1776, and began his new career by forming the ſeminary after the model of an academy which had ſome time before been ſet up in the principality of Anhalt Deſſau by one Baſedow, a man of talents and learning, who gave to it the appellation of PHILANTHROPINE. The plan of this academy was very different from thoſe of the univerſities; for its author profeſſed to conſider languages, ſciences, and the ornamental exerciſes, as mere acceſſories, his aim being to form the young mind to the love of mankind and of virtue, by a courſe of moral education certainly ſpecious, and apparently unexceptionable. To make this novel inſtitution the more extenſively uſeful, the rules by which the education was to be conducted were framed in ſuch a manner as, it was thought, would remove from the minds of Catholics, Lutherans, and Calviniſts, all uneaſineſs reſpecting the faith of their children, as it related to thoſe particular tenets which ſeparated them into different communions. It was even propoſed to baniſh from the philanthropine all *poſitive* religion whatever, and to inſtruct the youth educated there in the principles only of natural, or, as it was called, *philoſophical religion*.

This plan was peculiarly ſuited to Bahrdt's taſte, becauſe it left him at liberty to introduce into his academy any ſyſtem of religious or irreligious opinions that he pleaſed; a liberty of which he reſolved to avail himſelf, and, though now a doctor in theology, to outſtrip, in licentiouſneſs, even the founder of the philanthropine, who was not in orders. By meditating on the workings of his own mind, he had by this time formed his theory of human nature, which was indeed very ſimple. "The leading propenſities of the human mind (he ſays) are three; inſtinctive liberty, inſtinctive activity, and inſtinctive love." By theſe expreſſions we ſuppoſe he means, "innate *love* of liberty, inſtinct prompting to action, and the ſexual appetite:" and he immediately adds, that "if a man is obſtructed in the gratification of any of theſe propenſities, he ſuffers an injury. The buſineſs therefore of a good education is to teach us how they are to be gratified in the higheſt degree."

That ſuch an education would be approved of by the uncorrupted natives of Switzerland was hardly to be expected; and Bahrdt ſoon found his ſituation at Marſchlins as uncomfortable as it had been at Gieſſen. "The Griſons (he ſays) were a ſtrong inſtance of the immenſe importance of education. They knew nothing but their handicrafts; and their minds were as coarſe as their perſons." He quarrelled with them all, and was obliged to abſcond after lying ſome time in priſon.

From Marſchlins he went to Durkheim, a town in the palatinate, where his father had been miniſter, and where his literary talents were well known. After ſome little time he got an aſſociation formed for erecting and ſupporting a *Philanthropine* or houſe of education. A large fund was collected; and he was enabled to travel into Holland and England to engage pupils, and was furniſhed with proper recommendations.

In London he gained the friendſhip of a clergyman, whom he repreſents as a perſon in the higheſt degree accompliſhed. "With ſound judgment (ſays Bahrdt), great genius, and correct taſte, he was perfectly a man of the world. He was my friend, and the only perſon who warmly intereſted himſelf for my inſtitution. To his earneſt and repeated recommendations I owe all the pupils that I got in England, and many moſt reſpectable connections; for he was univerſally eſteemed as a man of learning and of the moſt unblemiſhed character. He was my friend, my conductor, and I may ſay my preſerver; for when I had not bread for two days, he took me to his houſe, and ſupplied all my wants."

For ſo much kindneſs the reader doubtleſs ſuppoſes that the heart of Bahrdt overflowed with gratitude; but if ſuch be his opinion, he is a ſtranger to the principles of thoſe who have on the continent of Europe aſſociated for the purpoſe of enlightening the world. This amiable man, whoſe character is here ſo juſtly drawn, was afterwards depicted by the monſter whom he had ſaved from periſhing by hunger, as a wretch loſt to all ſenſe of ſhame and decency, as an apoſtate from the Chriſtian faith, and as a notorious frequenter of the London brothels! Fortunately he was able to vindicate his character completely from this ſlanderous abuſe, and to convict Bahrdt of having publiſhed what *could not poſſibly be true.*

This ungrateful liar returned from England, and carried into execution his plan of the Philanthropine. The caſtle of Count Leining Hartzburgh at Heideſheim, having gardens, park, and every handſome accommodation, had been fitted up for it; and in 1778 it was conſecrated by a ſolemn religious feſtival. But his old misfortunes purſued him. He had indeed no colleagues with whom he could quarrel; but his *avowed* publications became every day more obnoxious; and when any of his *anonymous* pieces had a great run, he could not ſo far ſtifle his vanity as to conceal that he was the author. Of theſe pieces ſome were ſhocking to decency, and others ſo horribly injurious to the characters of the moſt reſpectable men in the ſtate, that he was continually under the correction of the courts of juſtice. It was hardly poſſible for a man of letters to be in his company, and not ſuffer by it; for it was his conſtant practice to attribute every ſtep which he took towards atheiſm, to the force of the arguments urged by ſome of his friends.

To be his friend, or to obtain his applauſe, was indeed ſo great a misfortune, that when the reader ſees any perſon celebrated by Dr Bahrdt, in the beginning of a book, for ſound ſenſe, profound judgment, accurate reaſoning, or praiſed for acts of friendſhip to himſelf, he may be aſſured, that before the cloſe of the book this man ſhall be repreſented as having in private converſation convinced the author, that ſome doctrine, cheriſhed and venerated by all Chriſtians, is a piece of knaviſh ſuperſtition.

Dr Bahrdt had married, while at Gieſſen, a woman with a ſmall fortune: but ſuch a ſtranger was he to the delicacies of wedded love, ſo loſt indeed to all ſenſe of decency, that he contrived one day to entice his wife *naked* into the bath in the garden of his Philanthropine, where, in the water, he, being alſo *naked*, toyed with her in the ſight of all his pupils. It was his boaſt that he held his opinions independent of all mankind, and was indifferent whether they procured him praiſe or reproach: but it appears from this fact, that he was, equally regardleſs of the praiſe or cenſure which might be attached to his actions; for ſurely the groſſeſt hog that ever before him battened in the Epicurean ſty would not have preſented ſuch an exhibition to boys.

The conſequence of all this was, that he was obliged to fly from Heideſheim, leaving his ſureties in the Philanthropine to pay about 14,000 dahlers, beſides debts without number to his friends. He was impriſoned at Dienheim; but being ſoon releaſed, he ſettled at Halle, where he ſunk to be the keeper of a tavern and billiard-table. His houſe became of courſe the reſort and the bane of the ſtudents in the univerſity, and he was obliged to leave the city. He had ſome how got money ſufficient to purchaſe a little vineyard, pleaſantly ſituated in the neighbourhood. This he fitted up with every accommodation that could invite the ſtudents, and called it *Bahrdt's Ruhe* (Bahrdt's repoſe) where he lived for two years, directing the operations of a ſecret ſociety called the GERMAN UNION, FOR ROOTING OUT SUPERSTITION AND PREJUDICES, AND FOR ADVANCING TRUE CHRISTIANITY.

With Bahrdt's qualifications for advancing the intereſts of genuine Chriſtianity, the Chriſtian reader is already ſufficiently acquainted; but he will not wonder at his appointment to this high office, when he is informed that the GERMAN UNION is nothing more than a ſpawn of the ſecret ſociety of *Illuminati* (ſee ILLUMINATI in this Supplement); and that its object is to aboliſh the religion of the goſpel, and to teach in its ſtead the fataliſm of the Stoics. With this view Chriſtianity is conſidered in the UNION as a myſtical ſociety, and its Divine Founder as the grand maſter of a lodge! The apoſtles Peter, James, John, and Andrew, were the ELECT, brethren of the *third* degree, and initiated into all the myſteries. The remaining apoſtles were only of the *ſecond* degree; and the ſeventy-two, of the *firſt*: a degree into which ordinary Chriſtians may be admitted, and prepared for farther advancement. The great myſtery is, that J—— C—— was a NATURALIST, and taught the doctrine of a ſupreme mind, the ſpectator but not the governor of the world.

To propagate theſe impious and abſurd notions, Bahrdt publiſhed many books of the moſt antichriſtian tendency, and ſome of them calculated to make their readers ſhake off all moral obligation. But the labours of the ſociety were not confined to religion: it inculcated on its members the moſt dangerous maxims of civil conduct: for, as we learn from Bahrdt himſelf, the objects at which the Union aimed were—*Advancement of ſcience—a general intereſt and concern for arts and learning—excitement of talents—check of ſcribbling—good education*—LIBERTY—EQUALITY—*hoſpitality*—DELIVERY OF MANY FROM MISFORTUNES—*union of the learned—and at laſt—perhaps—Amen.*

What the meaning of this enigmatical concluſion is we can only gueſs; and we agree with the real philoſopher from whom we have taken this account, that our conjectures cannot be favourable. Bahrdt was a villain, and could be aſſociated only with villains, whoſe affairs he managed with the help of an old man, who lived at bed and board in his houſe for about ſix ſhillings a week, and diſcharged the office of ſecretary to the UNION.

When he had toiled in this cauſe near two years, ſome of the ſecrets of the Union tranſpired; his former conduct and his conſtant imprudence made him ſuſpected; his aſſociated friends lodged informations againſt him; his papers were ſeized; and he himſelf was ſent to priſon, firſt at Halle and then at Magdeburg. After ſomething more than a year's confinement, he was ſet at liberty, and returned to his *Ruhe*, not, alas! to live at eaſe, or to exhibit ſymptoms of repentance, but to lie down on a ſick-bed, where, after many months ſuffering of increaſing pain, he died on the 23d of April 1793.

unaffected; and during his magiſtracy he ſpent a part of his fortune in relieving the wants of the poor. His virtue remained as untainted in his various public ſtations as in the ſweet retirement of domeſtic life.

Such is the encomium paſſed upon this philoſopher and ſtateſman by no leſs a man than the celebrated aſtronomer M. de la Lande; but to thoſe who are not infected with the *mania* of freedom, it will doubtleſs appear greatly exaggerated. That M. Bailly was a man of eminence in the republic of letters, is known to all the learned of Europe; that in his political conduct he meant to promote the good of his country, it would certainly be preſumptuous in us to deny; and that he ſuffered unjuſtly, is incontrovertible: But let it be remembered, that he ſuffered in a ſtorm, which he exerted all his abilities to raiſe; and that he ſet an example of injuſtice, when he concurred in the degradation of the privileged orders, and in the violent confiſcation of the property of the church.

BAIRDSTOWN, or *Beardſtown*, in Nelſon co. Kentucky, is a flouriſhing town, of 216 inhabitants, ſituated on the head waters of Salt river, 50 miles S. E. from Louiſville, and nearly the ſame diſtance S. W. from Danville.—*Morſe.*

BAKERSFIELD, a newly ſettled townſhip in Franklin co. Vermont, formerly in Chittenden co. In 1790 it had only 13 inhabitants.—*ib.*

BAKERSTOWN, in Cumberland co. Diſtrict of Maine, contains 1276 inhabitants; 162 miles N. E. from Boſton.—*ib.*

BALD EAGLE, or *Warrior Mountains*, lie about 200 miles W. of Philadelphia, in Bedford co. Pennſylvania, and forms the weſtern boundary of Bald Eagle Valley.

Bald Eagle is likewiſe the name of a river which runs a N. E. courſe 44 miles and falls into the W. branch of Suſquehanna River. The head water of Huron River which falls into Lake Erie, is called Bald Eagle Creek.—*ib.*

BALD EAGLE VALLEY, or, as it is commonly called, *Sinking Spring Valley*, lies upon the frontiers of Bedford co. in Pennſylvania, about 200 miles W. from Philadelphia. It has on the E. a chain of high, rugged mountains, called the *Canoe Ridge*, and on the W. the *Bald Eagle*, or Warrior Mountains. This is a pleaſant vale, of limeſtone bottom, 5 miles in extent where wideſt; and in the vicinity are great quantities of lead ore. It contained, in 1779, about 60 or 70 families, living in log-houſes, who formed, in the ſpace of 7 or 8 years, ſeveral valuable plantations, ſome of which are remarkably agreeable on account of their ſituation.

During the late war with Great Britain, lead was much wanted, and very difficult to be procured, which induced a company, under the promiſes of the ſtate, to ſettle here, and eſtabliſh a regular ſet of works. A fort of logs was erected for the protection of the miners; and a conſiderable quantity of ore was produced, from which lead enough was made, to give a competent idea of the real value of the mines in general. The danger of the ſituation, however, while an Indian war continued, occaſioned the failure of the undertaking.

The lead ore was of many kinds; ſome in broad flakes, and others of the ſteely texture. Several regular ſhafts were ſunk to a conſiderable depth; one of which was on the hill, upon which the fort was erected, and from which many large maſſes of ore were procured; but, not forming a regular vein, it was diſcontinued, and another opened about a mile from the fort, nearer to Frank's Town. Here the miners continued until they finally relinquiſhed the buſineſs. When they firſt began, they found in the upper ſurface or vegetable earth, ſeveral hundred weight of cubic lead ore, clean and unmixed with any ſubſtance whatever, which continued as a clue, leading them down through the different ſtrata of earth, marl, &c. until they came to the rock, which is here in general of the limeſtone kind.

Among other curioſities of this place, is that called *the Swallows*, which abſorb ſeveral of the largeſt ſtreams of the valley, and after conveying them ſeveral miles under ground, in a ſubterraneous courſe, return them again upon the ſurface. Theſe ſubterraneous paſſages have given riſe to the name, *Sinking Spring Valley*. Of theſe the moſt remarkable is called the *Arch Springs*, and run cloſe upon the road from the town to the fort. It is a deep hollow, formed in the limeſtone-rock, about 30 feet wide, with a rude natural ſtone arch hanging over it, forming a paſſage for the water, which it throws out with ſome degree of violence, and in ſuch plenty as to form a fine ſtream, which at length buries itſelf again in the bowels of the earth. Some of theſe pits are near 300 feet deep; the water at the bottom ſeems in rapid motion; and is apparently as black as ink; though it is as pure as the fineſt ſprings can produce. Many of theſe pits are placed along the courſe of this ſubterraneous river, which ſoon after takes an opportunity of an opening at a declivity of the ground, and keeps along the ſurface among the rocky hills for a few rods, then enters the mouth of a large cave, whoſe exterior aperture would be ſufficient to admit a ſhallop with her ſails full ſpread. In the inſide it keeps from 18 to 20 feet wide. The roof declines as you advance, and a ledge of looſe, rugged rocks, keeps in tolerable order, on one ſide, affording means to ſcramble along. In the midſt of this cave is much timber, bodies of trees, branches, &c. which being lodged up to the roof of this paſſage, ſhews that the water is ſwelled up to the very top during freſhes. This opening in the hill continues about 400 yards, when the cave widens, after you have got round a ſudden turning (which prevents its being diſcovered till you are within it) into a ſpacious room, at the bottom of which is a vortex, the water that falls into it whirling round with amazing force; ſticks, or even pieces of timber, are immediately abſorbed, and carried out of ſight, the water boiling up with exceſſive violence, which ſubſides by degrees, until the experiment is renewed.

From the top of the Bald Eagle Mountains is a fine proſpect of thoſe of the Allegany, ſtretching along until they ſeem to meet the clouds. Much ſlate is found here, with ſtrong ſigns of pit coal. Such as viſit theſe parts muſt croſs the Juniata river 3 or 4 times from Standing Stone or Huntington, to the fort; from which it is computed to be about 22 miles diſtance.—*ib.*

BALIOL (John), the competitor with Bruce for the crown of Scotland, was not (as he is ſaid to have been in the *Encyclopædia)* the brother of King Alexander, but the great grandſon of David Earl of Huntington, third ſon of King David I.

BALLISTIC Pendulum, an ingenious machine invented by Benjamin Robins, for aſcertaining the velocity of military projectiles, and conſequently the force of fired gunpowder. It conſiſts of a large block of wood, annexed to the end of a ſtrong iron ſtem, having a croſs ſteel axis at the other end, placed horizontally, about which the whole vibrates together like the pendulum of a clock. The machine being at reſt, a piece of ordnance is pointed ſtraight towards the wooden block or ball of this pendulum, and then diſcharged: the conſequence is this; the ball diſcharged from the gun ſtrikes and enters the block, and cauſes the pendulum to vibrate more or leſs according to the velocity of the projectile or the force of the blow; and by obſerving the extent of the vibration, the force of that blow becomes known, or the greateſt velocity with which the block is moved out of its place, and conſequently the velocity of the projectile itſelf which ſtruck the blow and urged the pendulum.

Hutton's Dictionary.

BALTIMORE *Co.* in Maryland, lies between Patapſco and Gunpowder rivers, the former dividing it from Ann Arundel co. on the S. and S. W. Gunpowder and Little Gunpowder ſeparating it from Harford co. on the E. and N. E. It has Frederick co. on the W. and N. W. Pennſylvania on the N. and Cheſapeak Bay on the S. E. Beſides the rivers which bound it, and their branches, this county has Back and Middle rivers, between the two former, but they are rather arms of Cheſapeak bay, than rivers. Back river, 4 or 5 miles E. of Patapſco, receives two ſmall ſtreams; the N. weſternmoſt is called Herring Run. Middle river has little or no ſupply of freſh water. There are numerous iron works in this county; and it contains 25,434 inhabitants, including 5,877 ſlaves. Its chief town is Baltimore.—*Morse.*

Baltimore, (See Encycl.) From the head of Elk river at the head of the bay to Baltimore, is about 60 miles. The town is built around what is called the baſon, reckoned one of the fineſt harbors in America. The water riſes 5 or 6 feet at common tides. It is divided into what is called the town and Fell's Point, by a creek; over which are two bridges: but the houſes extend, in an irregular manner, from the one to the other. At Fell's Point the water is deep enough for ſhips of burden, but ſmall veſſels only go up to the town.

The ſituation is low, and was formerly thought unhealthy, but, by its rapid increaſe, improvements have taken place, which have corrected the dampneſs of the air, and it is now judged to be tolerably healthy. In 1787, it contained 1955 dwelling houſes; of which 1200 were in the town, and the reſt at Fell's Point. It then contained 152 ſtores. The number of the inhabitants of the town and precincts, in 1791, were 13,503, including 1,255 ſlaves. The number of houſes and inhabitants have been greatly increaſed ſince.

Before the emigration of the French people from Cape François and other iſlands, the houſes had increaſed to 2,300. Thoſe unfortunate people, flying from their mercileſs countrymen, who had burned and pillaged their cities and towns, and murdered their relations and friends, found here an hoſpitable aſylum, after ſufferings hardly paralleled in the annals of hiſtory.

Here are 9 places of public worſhip, which belong to Roman Catholics, German Calviniſts and Lutherans, Epiſcopalians, Preſbyterians, Baptiſts, Methodiſts, Quakers, and Nicolites, or New Quakers, who all live together in peace. It is inhabited by people from moſt parts of Europe. The principal ſtreet is Market Street, which runs nearly E. and W. a mile in length, parallel with the water. This is croſſed by a number of other ſtreets, which run from the water; a number of which, particularly Calvert and Gay ſtreets, are well built. N. and E. of the town, the land riſes, and preſents a noble view of the town and bay. In 1790, this city owned 27 ſhips, 1 ſnow, 31 brigantines, 34 ſchooners, and 9 ſloops—Total 102; tonnage 13,564. The exports in the ſame year amounted to 2,027,770, and the imports to 1,945,899 dollars. The exports in July, Auguſt, and Sept. in 1790, amounted only to 343,584 dollars; but in theſe months in 1795, they amounted to 1,675,748 dollars. The affairs of the town are managed by a board of town commiſſioners, a board of ſpecial commiſſioners, and a board of wardens; the firſt board fills its own vacancies, and is perpetual; the two laſt are appointed by electors, choſen every 5th year by the citizens. It is 53 miles S. W. from Elktown, 176 N. E. from Richmond in Virginia; 50 N. E. from the city of Waſhington, and 103 S. W. from Philadelphia. N. lat. 39. 21. W. long. 77. 48.—*ib.*

BANGOR, a townſhip in Hancock co. Diſtrict of Main, on the weſtern ſide of Penobſcot river, 25 miles from its mouth at Belfaſt Bay; 65 N. W. by W. from Machias; 63 N. E. from Hallowell, and 280 N. E. from Boſton.—*ib.*

BANKA (ſee Banca, *Encycl)* is noted throughout Aſia for its tin mines. It lies oppoſite to the river Palambang, in the iſland of Sumatra, on which the ſovereign of Banka, poſſeſſor alſo of the territory of Palambang, keeps his conſtant reſidence. This prince maintains his authority over his own ſubjects, and his independence of the neighbouring ſovereigns, chiefly by the aſſiſtance of the Dutch, who have a ſettlement and troops at Palambang, and enjoy the benefit of a contract with the king of Banka for the tin which his ſubjects procure from that iſland. Such at leaſt was the caſe in 1793, when Lord Macartney touched at Banka on his way to China. At that period the ſovereign compelled his ſubjects, and probably does ſo at preſent, to deliver the tin to him at a low price, and ſold it to the Dutch at a ſmall advance, purſuant to his contract. Thoſe miners, from long practice, have arrived at great perfection in reducing the ore into metal, employing wood as fuel in their furnaces, and not foſſile coal, or *coak*, which is ſeldom ſo free from ſulphur, as not to affect the malleability of the metal. It is ſometimes preferred therefore to European tin at the Canton market; and the profit upon it to the Dutch company was, at the period mentioned above, ſuppoſed to have long been not leſs than L. 150,000 a year. Into whoſe hands this trade has now fallen we know not; probably it is in a great degree neglected.

BANTAM, the capital of a kingdom of the ſame name in the iſland of Java, is, in the *Encyclopædia*, ſaid to be a large town with a good harbour and fortified caſtle. Sir George Staunton, however, who viſited Bantam ſince that article was publiſhed, gives a very different account both of the town and of its harbour. Once indeed it was a place of conſiderable conſequence, being the great mart for pepper and other ſpices, whence they were diſtributed to the reſt of the world. The chief factory of the Engliſh as well as Dutch Eaſt India Company was ſettled there. The merchants of Arabia and Hindoſtan reſorted to it. Its ſovereigns were ſo deſirous of encouraging trade, by giving ſecurity to foreign merchants againſt the violent and revengeful diſpoſition of the natives, that the crime of murder was never pardoned when committed againſt a ſtranger, but might be committed by a foreigner for a fine to the relations of the deceaſed. This place flouriſhed for a conſiderable time; but the Dutch having conquered the neighbouring province of Jacatra, where they ſince have built Batavia, and transferred their principal buſineſs to it, and the Engliſh having removed to Hindoſtan and China, and trade in other reſpects having taken a new courſe, Bantam was reduced to a poor remnant of its former opulence and importance. Other circumſtances have accelerated its decline. The bay is ſo choked up with daily acceſſions of new earth waſhed down from the mountains, as well as by coral ſhoals extending a conſiderable way to the eaſtward, that it is inacceſſible at preſent to veſſels of burden; even the party who went there from the Lion, the ſhip which carried Lord Macartney to China, was obliged to remove from her pinnace into a canoe, in order to reach the town. With the trade of Bantam the power of its ſovereign declined. In his wars with other princes of Java he called in the aſſiſtance of the Dutch; and from that period he became in fact their captive. He reſides in a palace, built in the European ſtyle, with a fort garriſoned by a detachment from Batavia, of which the commander takes his orders not from the king of Bantam, but from a Dutch chief or governor, who lives in another fort adjoining the town, and nearer to the ſeaſide. His Bantameſe majeſty is allowed, however, to maintain a body of native troops, and has ſeveral ſmall armed veſſels, by means of which he maintains authority over ſome parts of the ſouth of Sumatra. His ſubjects are obliged to ſell to him all the pepper they raiſe in either iſland, at a low price, which he is under contract with the Dutch to deliver to them at a ſmall advance, and much under the marketable value of that commodity. The preſent king joins the ſpiritual to the temporal power, and is high prieſt of the religion of Mahomet; with which he mingles, indeed, ſome of the rites and ſuperſtitions of the aboriginal inhabitants of Java; adoring, for inſtance, the great banyan, or Indian fig-tree, which is likewiſe held ſacred in Hindoſtan, and under which religious rites might be conveniently performed; in like manner, as all affairs of ſtate are actually tranſacted by the Bantameſe under ſome ſhadowing tree by moonlight. To complete the ruin of Bantam, a fire ſome time ago deſtroyed moſt of the houſes, and few have been ſince rebuilt.

BANYAN TREE. See FICUS, *Encycl.*

BRITISH BARILLA, is the name given by Mr James King of Newcaſtle upon Tyne, to a material invented by him to ſupply the place of Spaniſh barilla in the making of crown window-glaſs, broad window-glaſs, and glaſs bottles, as alſo in the manufacturing of ſoap and alum. For theſe purpoſes he affirmed that it anſwered much better than any other material then in uſe; and in conſequence of that affirmation he obtained a patent for his invention, dated March 4, 1780.

Though we can hardly allow to this invention all the merit claimed for it by its fond author, yet as it *may* be of uſe to different manufacturers, we ſhall lay before our readers his method of making the Britiſh barilla. It is as follows: "Take a certain quantity of aſhes obtained by burning the loppings or branches of aſh, oak, beech, elm, alder, or any other kind of green wood or bramble: Take an equal quantity of the aſhes obtained by burning the green vegetables known by the name of fern, brecon, bean and pea-ſtraw, whins, common field and high-way thiſtles, the ſtalks of rape or muſtard-ſeed, or the bent or ruſhes that grow by the ſea ſhore." Though we know not in what qualities the aſhes obtained from the former ſubſtances differ from thoſe obtained from the latter, the author, as if the difference was very great, directs theſe equal quantities to be mixed together, ſifted through a fine ſieve, and laid upon a boarded floor, where a quantity of ſoapers waſte-aſhes, equal to the whole compound maſs, is to be added to it, and well mixed with it by means of a ſhovel or other inſtrument. To this mixture of vegetable aſhes and ſoapers waſte-aſhes is to be added a quantity of fine quick-lime, in the proportion of one hundred weight to twelve hundred of the blended aſhes, and the lime and aſhes are to be well mixed together. After this the whole is to be put into an iron pan, into which is to be poured a quantity of ſea water ſufficient, ſays the author, to diſſolve the aſhes and lime; and the whole is to be ſtirred with an iron rake till it incorporate. This being done, a coal fire is to be lighted up under the pan, and kept burning for two days and two nights without intermiſſion, additional quantities of ſea water being conſtantly ſupplied to impregnate the materials with ſaline matter ſufficient for calcination in a reverberating furnace or calcar. In this calcar the ſaline maſs, which was boiled in the pan, is by intenſe heat to be diſſolved, and kept in a ſtate of fuſion for the ſpace of an hour; during which time the volatile part flies off, and leaves remaining a fixed alkaline ſalt, which, cooled in iron pans, is the Britiſh barilla, and has the appearance of Spaniſh barilla. See BARILLA, *Encycl.*

BARNEGAT, the name of a ſmall village of 8 or 10 houſes, on the eaſt bank of Hudſon river, 5 miles S. of Poughkeepſie, and 75 N. of N. York. The ſole buſineſs of the few inhabitants of this place, is burning lime, from the vaſt quantities of lime ſtone which are found here. Their lime is marketed in N. York, whither they carry it in great quantities annually.—*Morſe.*

BARNET, a townſhip in Caledonia co. Vermont, formerly in Orange co. containing 477 inhabitants, and 112 miles N. E. from Bennington. The lower bar of the 15 mile falls in Connecticut River is ſituated at the N. E. corner of this townſhip. Into that river it ſends Stephens River which riſes in Peachum, the adjoining town on the W.—*ib.*

BARNSTABLE, the *Mattacheeſe*, or *Mattacheeſet* of the ancient Indians, is a port of entry and poſt town, and is the ſhire town of Barnſtable co. It extends acroſs the peninſula, and is waſhed by the ſea on the N. and S. having Sandwich, and the diſtrict called Marſhpee or Maſhpee on the W. is about 5 miles broad, and 9 long; 67 miles S. eaſterly from Boſton. Sandy Neck, on the N. ſhore, runs E. almoſt the length of the town, and forms the harbor, emboſoming a large body of ſalt marſh. The harbor is about a mile wide, and 4 long; in which the tide riſes from 8 to 14 feet. It has a bar running off N. E. from the Neck ſeveral miles, which prevents the entrance of large ſhips; but ſmall veſſels may paſs any part of it at high water; and where it is commonly croſſed, it ſeldom has leſs than 6 or 7 feet at low water.

There is another harbor on the S. called *Lewis's Bay*. Its entrance is within Barnſtable, and it extends almoſt 2 miles into Yarmouth. It is commodious and ſafe, and is completely land locked; and has 5 feet water at a middling tide.

A mile or two to the weſtward, and near the entrance of Lewis's Bay, lies *Hyanis Road*. It is formed principally by an iſland, joined by a beach to Yarmouth, which together, make the outſide of the bay before mentioned. The S. head of this iſland is called Point Gammon. Oyſter Bay, near the S. W. limit of the town, admits ſmall veſſels; and which, with Lewis's Bay, has in years paſt produced excellent oyſters, in great quantities; though they are now much reduced.

There are about 20 or 30 ponds in Barnſtable. The land here produces about 25 buſhels of Indian corn to an acre, and rye and other grain in proportion. Wheat and flax are cultivated; the latter with ſucceſs. From 12 to 18,000 buſhels of onions are raiſed for the ſupply of the neighboring towns. Upwards of 100 men are employed in the fiſhery, which is yearly increaſing. Whales ſeldom come into Maſſachuſetts Bay now, and that fiſhery is diſcontinued. No quarrels with the ancient natives of the country are recorded in the accounts of this town, where the Engliſh ſettlers of New-England firſt landed, Nov. 11, 1620. The people, 2610 in number, are generally healthy; and many inſtances of longevity are to be met with. Numbers of the farmers are occaſionally ſeamen; and this town has afforded, and continues to furniſh many maſters of veſſels and mariners who ſail from other ports. N. lat. 41. 43.—*Morſe.*

BARNSTEAD, a townſhip in Stafford co. New-Hampſhire, containing 807 inhabitants; 32 miles N. W. of Portſmouth, and 16 E. by S. from Canterbury, on Connecticut river.—*ib.*

BARRE', a townſhip in Worceſter co. Maſſachuſetts, containing 1613 inhabitants, 24 miles N. W. of Worceſter, and 66 W. of Boſton, deriving its name from Col. Barré, a Britiſh ſenator, who on the eve of the late war, plead the cauſe of America, in the Britiſh houſe of commons, with great, but unſucceſsful energy. This town has good paſtures, and here are fatted multitudes of cattle; and it is ſuppoſed, more butter and cheeſe is carried from hence to the market, annually, than any other town of the ſame ſize in the State. —*ib.*

Barre', a townſhip in Huntingdon co. Pennſylvania.—*ib.*

BARRELL's *Sound*, on the N. W. Coaſt of America, called by the natives *Conget-hoi-toi*, is ſituated about 6 leagues from the ſouthern extremity of Waſhington, or Charlotte iſlands, in a N. W. direction, about N. lat. 52. W. long. 131. from Greenwich. It has two inlets; one on the E. the other W. ſide of the iſland; the latter is the beſt, the other is dangerous. The ſhores are of a craggy black rock; the banks lined with trees of various kinds, as pines, ſpruce, hemlock, alder, &c. Mr Hoſkins, in the ſummer of 1791, meaſured one of theſe trees, which was *ten fathoms* in circumference. On one ſide of it a hole had been cut, large enough to admit a man; within was a ſpacious and convenient room, which had apparently been dug and burnt out with much labor. Mr Hoſkins concluded that it muſt have been occaſionally inhabited by the natives; as he found in it a box, fireworks, dried wood, and ſeveral domeſtic utenſils. This ſound was named after Joſeph Barrell, Eſq. of Charleſtown, *(Maſſ.)* and was firſt viſited by Capt. Gray, in the Waſhington, in 1789.—*Morſe.*

BARREN *Creek*, riſes in the N. W. corner of Delaware ſtate, runs about 9 miles S. weſterly, and empties into Nanticoke river. A triangular tract of land in the N. part of Somerſet co. Maryland, is encloſed between this creek on the S. Delaware ſtate E. and Nanticoke river on the W. and N. W.—*ib.*

BARRINGTON, a townſhip in Queen's co. Nova-Scotia, on the S. ſide of the bay of Fundy; ſettled by Quakers from Nantucket Iſland.—*ib.*

Barrington, a townſhip in Stafford co. N. Hampſhire, about 30 miles N. W. from Portſmouth, incorporated in 1722, containing 2470 inhabitants. Allum is found here; and the firſt ridge of the *Froſt Hills*, one of the three inferior ſummits of Agamenticus, is continued through this town. Its ſituation is very healthy; *e. g.* 14 of the firſt ſettlers in 1732, were alive in 1785, who were between 80 and 90 years old. —*ib.*

Barrington, a townſhip in Briſtol co. Rhode-Iſland, on the S. weſtern ſide of the N. W. branch of Warren river, little more than 2½ miles N. W. of Warren, and about 7 S. E. from Fox Point, in the town of Providence. It contains 683 inhabitants, including 12 ſlaves.—*ib.*

Barrington, Great, is the ſecond townſhip in rank in Berkſhire co. Maſſachuſetts. It contains 1373 inhabitants, and lies 140 miles W. from Boſton, and ſouth of Stockbridge, adjoining.—*ib.*

BARTHELEMI (Jean Jacques), the Neſtor of French literature, was a man ſo eminent for his knowledge of antiquities, that every claſſical reader muſt be intereſted in his fate. He was born, we believe, at Paris about the latter end of the year 1715; and being educated for the ſervice of the church, he became prior of Courcay, keeper of the medals and antiques in the French king's cabinet, and in 1747 was elected a member of the Academy of Inſcriptions. From that period his life was wholly devoted to letters; and in recording the principal events of it, we can only enumerate, in their order, his various publications.

A diſſertation of his on the river Pactolus was read 1748 *(Hiſt. de l'Acad.* X. 29.); Reflections on a Medal of Xerxes, King of Arſamata *(Mem. de l'Acad.* XXXVII. 171.), found, or ſaid to be found, by Fourmont in the temple of Apollo Anycleus (XXXIX. 129.); Eſſay on Numiſmatic Palæography, *ib.* 223; Diſſertation on two Samaritan Medals of Antigonus King of Judea, *ib.* 257; Remarks on ſome Inſcriptions publiſhed excurſions in different parts from Canada to Florida. Botany being his favourite purſuit he ſoon made ſuch proficiency therein that the great Linnæus ſaid in one of his letters, that he was the greateſt natural botaniſt in the world. His progreſs in botany, natural hiſtory and philoſophy, attracted the notice and eſteem of the principal literary and eminent characters in America, among whom were James Logan, Eſq. Dr Franklin and Dr Kennerſley of Philadelphia, Dr Colden of New York and Dr Clayton of Virginia, and introduced him to the correſpondence and friendſhip of Peter Collinſon, Eſq. which continued for nearly fifty years and terminated only with life; Lord Petre, Dr Dillenius, Sir Hans Sloane, Mr Cateſby, Dr Fothergill, Dr Hill, Gronovius, Linnæus, Profeſſor Kalm, M. Wrangle, &c. who furniſhed him with ſuch books, philoſophical apparatus, &c. as his genius and ſituation required, thereby leſſening the difficulties with which he had to ſtruggle in a newly ſettled country, and promoting the object which his benevolent mind had contemplated in communicating his diſcoveries and collections to Europe. Theſe communications occaſioned him to be employed in collecting whatever was new and curious to furniſh and ornament the European gardens and plantations with the productions of the New World. His induſtry and ſucceſs in the purſuit of ſcience procured him fellowſhip in many literary and ſcientific ſocieties in Europe, as thoſe of London, Edinburgh, Stockholm, &c. and at laſt he was appointed American Botaniſt to his Britannic Majeſty George the Third, in which appointment he continued till his death in September 1777, in the Seventy-ſixth year of his age.

He employed much of his time in excurſions through the provinces then ſubject to England; chiefly in autumn, when his agricultural avocations leaſt required his preſence at home. The object of theſe journeys was to collect curious and non-deſcript vegetables, foſſils, &c. His ardour in theſe purſuits was ſuch that at the age of 70 he made a journey into Eaſt Florida to explore the natural productions of that country. His travels among the Native Indians were attended with much danger and difficulty, and the different parts of the country, from the ſhores of Lakes Ontario and Caiuga to the ſource of the river St Juan in E. Florida, contributed through his hands to enrich and embelliſh the gardens and foreſts of Europe with elegant flowering ſhrubs, plants, and uſeful and ornamental trees.

He was an ingenious mechanic, ſeveral monuments of which ſtill remain at the houſe in which he lived which he built himſelf, after quarrying the ſtone: and he was often his own maſon, carpenter, black-ſmith, &c. and generally made his own farming utenſils.

His ſtature was rather above the middle ſize, erect and ſlender, a ſandy complection, cheerful countenance, with an air of ſolemnity, his manners modeſt and gentle, an amiable diſpoſition and liberal mind, a lover of charity and ſocial order, he was never known to enter into a litigious conteſt with any one, active and temperate, but always maintained a plentiful table, and annually on new year's day he made an entertainment at his own houſe, conſecrated to friendſhip and philoſophy. He was an advocate for liberty, and for the abolition of Negro ſlavery, and gave freedom to an excellent young African whom he had brought up, and who continued gratefully in his ſervice while he lived. Born and educated in the Society of Friends (called Quakers) he was a pious man. The following diſtich was engraved by himſelf on a ſtone in the wall over the front window of his own apartment.

> " 'Tis God alone, the Almighty Lord,
> " The Holy One by me ador'd."

JOHN BARTRAM, 1770.

BARYTES, one of the earths. See CHEMISTRY in this Supplement, Part I. Chap. iv.

BASTER, the name given by the Dutch at the Cape of Good Hope to the offspring of a white man and Hottentot woman.

BAT, an animal which has been deſcribed under its generic name VESPERTILIO in the *Encycl.* but ſince that article was written, we have met with an account of a new ſpecies, ſo very ſingular, that, if the veracity of our author can be depended on, it is well intitled to a place here. This ſpecies was diſcovered in the country of the Nimiquas, in the interior of Africa, by *M. Vaillant*, during the courſe of his ſecond travels, and is by him called the *oreillar* bat. To this title it has indeed a very good claim; for it has, he ſays, four ears, or at leaſt the external part of four ears, each ear being double; the outer fold, which ſerves as a covering to the inner, is very ample, being two inches eight lines high, and nearly as broad when ſtretched out. On the noſe alſo a membrane ſtands erect, one inch four lines in height, which might be taken for another ear, as it has exactly the ſhape of one. This membrane, as well as the ears and wings of the animal, are of a ruſty red, paler below than above. The body is only three inches long, and is covered with very fine greyiſh hair. Its width, from the tip of one wing to that of the other, is eight inches. The reader will pardon me, ſays our author, for inſerting theſe trifling details of meaſurement, of which I am not more fond than himſelf; but they appeared to me neceſſary here, to convey an accurate idea of the extraordinary length of the ears of this animal, which are certainly larger in proportion than thoſe of any other we are acquainted with, ſince they are only four lines, or the third part of an inch, ſhorter than the body itſelf.

BATAVIA, the capital of the Dutch ſettlements in the Eaſt Indies, has been already deſcribed under the article JAVA in the Encyclopædia. The following account of it, however, as well as of the country around it, and the manners and cuſtoms of its various inhabitants, as they preſented themſelves to Sir George Staunton in March 1793, will probably prove acceptable to many of our readers.

The city of Batavia, including the ſuburbs, conſiſts of near eight thouſand houſes, inhabited by Dutch, Chineſe, and natives of Java. The houſes of the Chineſe are low, and crammed with people. The Dutch houſes are well built, clean, and ſpacious, and their conſtruction for the moſt part well ſuited to the climate. The doors and windows are wide and lofty. The ground floors are covered with flags of marble, which being ſprinkled frequently with water, give a pleaſant coolneſs to the apartment; but a conſiderable proportion of thoſe was untenanted, which denoted a declining ſettlement. Among other circumſtances which announced the ſame, were thoſe of the Company's veſſels lying uſeleſs in the road, for want of cargoes to fill, or men to navigate them ; no ſhips of war to protect their commerce, even againſt pirates, who attacked their veſſels ſometimes in the ſight of Batavia road ; an invaſion threatened from the Iſle of France ; the place in no condition of defence, particularly againſt an enemy leſs affected by the climate than Europeans ; ſometimes as many of the troops in hoſpitals as fit for duty ; commiſſioners expected from Holland to reform abuſes. Such a commiſſion, implying a general ſuſpicion, could not be welcome ; nor was it quite certain whether, in ſome minds, its arrival or that of the enemy was deprecated the moſt cordially.

The fortifications of Batavia, though a place of ſo much importance, were not, when Sir George ſaw them, ſuch as would be deemed formidable in Europe ; but when the difficulties were conſidered of forcing the paſſage of the river, or of landing troops on other parts of the iſland, it might perhaps be thought of greater ſtrength than it would at the firſt view have credit for. The defences of the river were the water fort, ſituated at its entrance, having mounted or diſmounted fourteen guns and two howitzers. It conſiſted of a parapet, originally well conſtructed, retained by a wall ; but the parapet was much neglected, and the wall nearly deſtroyed by the conſtant working of the ſea. This fort was protected on the land ſide by a noxious ſwamp, and towards the ſea, on the north-weſt, by extenſive flats, over which even boats could not paſs. The only good approach was that by the channel, which it ſees and defends. The next work upon the river was on the weſt ſhore, about a quarter of a mile from the water fort. It is a battery mounting ſeven guns, bearing down the river. Oppoſite to this was a battery of ſix guns, facing the river, and two to the eaſtward. This formed one flank of a line that occupied the low land to the north-eaſt of the town. The line was a low breaſt-work of earth, that was ſcarcely diſcoverable. The canals which interſect the town joined the great canal or river, at the diſtance of half a mile from the entrance. Below the junction a boom was laid of wood, armed with iron ſpikes. A little above was the caſtle, a regular ſquare fort, but without ravelins or other outworks. It had two guns mounted on each flank, and two, or ſometimes three, on each face : they were not *en barbette*, nor properly *en embraſure*, but in a ſituation between both, having both their diſadvantages without the advantage of either. The wall was of maſonry, about 24 feet high. It had no ditch, but a canal ſurrounded it at ſome diſtance. It had no cordon. The length of the exterior ſide of the work was about 700 feet. The town is rectangular, three quarters of a mile long, and half a mile broad, incloſed by a wall of about 20 feet in height. Small projections were conſtructed, of various forms, at intervals of about 350 feet. Theſe generally mounted three guns each. It was alſo ſurrounded by a canal, having ſeveral ſluices. At ſhort diſtances from the town, three or four ſmall ſtar forts of earth were erected in particular paſſes, perhaps for defence againſt the inhabitants of the iſland.

The eſtabliſhment of regular troops was 1200 Europeans, of whom 300 were to be artillery, the reſt infantry. But as it was found impoſſible, on account of the climate, to keep the number complete, recourſe was had to the natives, of whom 500 were employed ; ſo that the eſtabliſhment of European regulars was reduced to 700. There were alſo 300 volunteers of the town, who were formed into two companies, but they were not diſciplined. Their regulars were very numerous, conſiſting of enrolled natives of Java, who were never embodied, and of Chineſe, of whom the Dutch were ſo jealous as to arm them with lances only. Much dependence was not to be placed on the exertions of either of theſe bodies in favour of the Dutch ; and as they loſe many of their European troops every year, their eſtabliſhment appeared too ſmall for any effectual reſiſtance. The chief protection of their ill-manned veſſels lying here, muſt be from the fortified iſland of Onruſt, well ſituated to command the channel that affords the principal paſſage into the road. The work upon that iſland was of a pentagonal form ; its baſtions were ſmall and low, not more than 12 feet the higheſt, and not always connected by curtains. A few batteries were lately conſtructed on the outſide of this work, that bore towards the ſea. On theſe and on the baſtions about 40 guns were mounted in different directions. South of theſe was another iſland, at the diſtance of a few hundred yards, on which two batteries, mounting together 12 guns, had been lately erected.

The caſtle is built of coral rock, brought from ſome of the adjoining iſlands, compoſed of that material ; and has the advantage of a fortification of brick, in which cannon ball is apt to bury itſelf without ſpreading ſplinters or ſhattering the wall. A part of the town wall is built of lava, which is of a dark blue colour, of a very hard denſe texture, emits a metallic ſound, and reſembles very much ſome of the lava of Veſuvius. It is brought from the mountains in the centre of Java, where a crater is ſtill ſmoking. No ſtone of any kind is to be found for many miles behind the city of Batavia. Marble and granite are brought thither from China, in veſſels belonging to that country, commonly called *junks*, which generally ſail for Batavia from the ports of the provinces of Canton and Fokien, on the ſouthern and ſouth-eaſt coaſts of that empire, laden chiefly with tea, porcelain, and ſilks.

The chief protection of Batavia againſt the attacks of a foreign enemy, ariſes from the havoc which it is well known the climate would make amongſt European troops. This was acknowledged to Lord Macartney by ſome of the Dutch officers themſelves, and even by one of the counſellors of the Indies. Such indeed is the climate, that there have been very few examples of ſtrangers remaining long in Batavia without being attacked by fever, which is the general denomination in that place for illneſs of every kind. Europeans ſoon after their arrival firſt become languid and feeble, and in a few weeks, or even in a few days, are taken ſeriouſly ill. The diſorder at firſt is commonly a tertian ague, which after two or three paroxyſms becomes a double tertian, and then a continued remittent, that frequently carries off the patient in a ſhort time. Many fall victims to the ſecond or third fit ; but in theſe caſes a conſtant delirium, and a great determination of the blood to the brain, accompany the other ſymptoms. In ſome it begins in a quotidian form, with regular intermiſſions for a day or two ; and then becomes a continued remittent, attended with the ſame fatal conſequences as the former. Of the Europeans of all claſſes who come to ſettle at Batavia, it is ſuppoſed that not half the number always ſurvives the year. The place reſembles in that reſpect a field of battle or a town beſieged. The frequency of deaths renders familiar the mention of them, and little ſigns are ſhewn of emotion or ſurpriſe on hearing that the companion of yeſterday is to-day no more. It is probable, female Europeans ſuffer leſs at Batavia than the men. The former ſeldom expoſe themſelves to the heat of the ſun, make frequent uſe of the cold bath, and live more temperately than the other ſex.

But it is not to thoſe who have lately arrived from Europe that this havoc is wholly confined. The greateſt number of the Dutch ſettlers, even thoſe who had reſided long in the country, appeared wan, weak, and languid, as if labouring with the "diſeaſe of death." Their place of reſidence, indeed, is ſituated in the midſt of ſwamps and ſtagnated pools, from whence they are every morning ſaluted with "a congregation of foul and peſtilential vapours," whenever the ſea breeze ſets in, and blows over this moraſs. The meridian ſun raiſes from the ſhallow and muddy canals, with which the town is interſected, deleterious miaſmata into the air; and the trees, with which the quays and ſtreets are crowded, emit noxious exhalations in the night.

The general reputation of the unhealthineſs of Batavia is indeed ſuch as to deter even Dutchmen, who can reſide at home with any comfort, from coming to it, notwithſtanding the temptations of fortunes to be quickly amaſſed in it. From this circumſtance it happens, that offices and profeſſions are often neceſſarily entruſted to perſons little qualified to fill them. One of the clergymen, and the principal phyſician of the place, were both ſaid to have originally been barbers. The United Provinces furniſh even few military recruits. The reſt are chiefly Germans, many of whom are ſaid to have been kidnapped into the ſervice. Though nominally permitted, after a certain length of time, to return home, they are in fact compelled to enliſt for a longer time, the pay being too ſcanty to allow them to ſave enough to defray the expence of their paſſage to Europe. The government is accuſed of the barbarous policy of intercepting all correſpondence between thoſe people and their mother country; by which means they are deprived of the conſolation of hearing from their friends, as well as of the chance of receiving ſuch aſſiſtance as might enable them to get home.

Difficult, however, as it is, on account of the climate, to recruit the army, ſuch is the deſire of accumulating wealth in a foreign land, that it draws annually great numbers of Chineſe as well as of Dutch to Batavia. Both indeed belong generally to the humbler claſſes of life, and are bred in ſimilar habits of induſtry in their own country; but the different circumſtances that attend them after their arrival in Batavia put an end to any further reſemblance between them. The Chineſe have there no way of getting forward but by the continuance of their former exertions in a place where they are more liberally rewarded, and by a ſtrict economy in the preſervation of their gains. They have no chance of advancing by favour, nor are public offices open to their ambition; but they apply to every induſtrious occupation, and obtain whatever either care or labour can accompliſh. They become in town retailers, clerks, and agents; in the country they are farmers, and are the principal cultivators of the ſugar-cane. They do at length acquire fortunes, which they value by the time and labour required to earn them. So gradual an acquiſition makes no change in their diſpoſition or mode of life. Their induſtry is not diminiſhed, nor their health impaired. The Dutch, on the contrary, who are ſent out by the Company to adminiſter their affairs in Aſia, become ſoon ſenſible that they have the power, wealth, and poſſeſſions of the country at their diſpoſal. They who ſurvive mount quickly into offices that are lucrative, and not to them laborious. They riſe to the dignity of governor-general and counſellors of the Indies, as the members of the Batavian government are called. Their influence likewiſe enables them to ſpeculate in trade with vaſt advantage. The drudgery and detail of buſineſs are readily undertaken by the Chineſe; while their principals find it difficult, under ſuch new circumſtances, to retain their former habits, or to reſiſt a propenſity to indolence and voluptuouſneſs, though often attended with the ſacrifice of health, if not of life. Convivial pleaſures, among others, are frequently carried to exceſs.

In ſeveral houſes of note throughout the ſettlement, the table is ſpread in the morning at an early hour: beſide tea, coffee, and chocolate, fiſh and fleſh are ſerved for breakfaſt; which is no ſooner over than Madeira, claret, gin, Dutch ſmall beer, and Engliſh porter, are laid out in the portico before the door of the great hall, and pipes and tobacco preſented to every gueſt, and a bright braſs jar placed before him to receive the phlegm which the tobacco frequently draws forth. This occupation continues ſometimes with little interruption till near dinner time, which is about one o'clock in the afternoon. It is not very uncommon for one man to drink a bottle of wine in this manner before dinner; and thoſe who have a predilection for the liquor of their own country ſwallow ſeveral bottles of Dutch ſmall beer, which they are told dilutes their blood, and affords plenty of fluids for a free perſpiration. Immediately before dinner, two men ſlaves go round with Madeira wine, of which each of the company takes a bumper as a tonic or whetter of the appetite. Then follow three females, one with a ſilver jar containing water, ſometimes roſe-water, to waſh; a ſecond with a ſilver baſon and low cover of the ſame metal, pierced with holes, to receive the water after being uſed; and the third with towels for wiping the hands. During dinner a band of muſic plays at a little diſtance: the muſicians are all ſlaves, and pains are taken to inſtruct them. A conſiderable number of female ſlaves attend at table, which is covered with a great variety of diſhes; but little is received, except liquors, into ſtomachs already cloyed. Coffee immediately follows dinner. The 24 hours are here divided, as to the manner of living, into two days and two nights; for each perſon retires, ſoon after drinking coffee, to a bed, which conſiſts of a mattraſs, bolſter, pillow, and chintz counterpane, but no ſheets; and puts on his night dreſs, or muſlin cap and looſe long cotton gown. If a bachelor, which is the caſe of much the greateſt number, a female ſlave attends to fan him while he ſleeps. About ſix they riſe, dreſs, drink tea, take an airing in their carriages, and form parties to ſpend the evening together to a late hour. The morning meetings conſiſt generally of men, the ladies ſeldom chooſing to appear till evening.

Few of theſe are natives of Europe, but many are deſcended from Dutch ſettlers here, and are educated with ſome care. The features and outlines of their faces are European; but the complexion, character, and mode of life, approach more to thoſe of the native inhabitants of Java. A pale languor overſpreads the countenance, and not the leaſt tint of roſe is ſeen in any cheek. While in their own houſes they dreſs like their ſlaves, with a long red checkered cotton gown deſcending to the ankles, with large wide ſleeves. They wear no head dreſs, but plait their hair, and faſten it with a ſilver bodkin on the top of the head, like the country girls in ſeveral cantons of Switzerland. The colour of their hair is almoſt univerſally black; they anoint it with the oil of the cocoa nut, and adorn it with chaplets of flowers. When they go abroad to pay viſits, or to take an airing in their carriages, and particularly when they go to their evening parties, they dreſs magnificently, in gold and ſilver ſpangled muſlin robes, with a profuſion of jewels in their hair, which however, is worn without powder. They never attempt to mould or regulate the ſhape by any fancied idea of elegance, or any ſtandard of faſhion; and conſequently formed a ſtriking contraſt with ſuch few ladies as were lately arrived from Holland, who had powdered hair and fair complexions, had contracted their waiſts with ſtays, wore large head dreſſes and hoops, and perſevered in the early care of forcing back the elbows, chin, and ſhoulders. Every native lady is conſtantly attended by a female ſlave handſomely habited, who, as ſoon as her miſtreſs is ſeated, ſits at her feet before her, on the floor, holding in her hands her miſtreſs's gold or ſilver box, divided into compartments, to contain areca nut, cardamom ſeeds, pepper, tobacco, and ſlacked lime; all which, mixed together in due proportions, and rolled within a leaf of betel, conſtitute a maſticatory of a very pungent taſte, and in general uſe. When in the public aſſemblies the ladies find the heat diſagreeable, they retire to free themſelves from their coſtly but inconvenient habits, and return without ceremony in a more light and looſe attire, when they are ſcarcely recognizable by ſtrangers. The gentlemen follow the example; and throwing off their heavy and formal dreſſes, appear in white jackets, ſometimes indeed adorned with diamond buttons. The elderly gentlemen quit their periwigs for nightcaps. Except in theſe moments the members of this government have always combined their perſonal gratification with the Eaſtern policy of ſtriking awe into vulgar minds, by the aſſumption of exterior and excluſive diſtinctions. They alone, for inſtance, appear abroad in crimſon velvet. Their carriages are diſtinguiſhed by peculiar ornaments. When met by others, the latter muſt ſtop and pay homage to the former. One of the gates of the city is opened only to let them paſs. They certainly ſucceed in ſupporting abſolute ſway over a vaſt ſuperiority in number of the deſcendents of the original inhabitants of the country, as well as of the ſlaves imported into it, and of the Chineſe attracted to it by the hope of gain; thoſe claſſes, though healthy, active, and as if quite at home, readily obeying a few emaciated Europeans. Such is the conſequence of dominion once acquired; the prevalence of the mind over mere bodily exertions, and the effect of the combination of power againſt divided ſtrength.

The native Javaneſe are in general too remote from civilization to have any wants that are not eaſily ſatiſfied in a warm and fertile climate. No attempt is made to enſlave their perſons; and they find the government of the Dutch leſs vexatious than that of others, who divide ſome ſhare of the ſovereignty of the iſland with them. The ſultan of Mataran rules to the eaſt, the emperor of Java in the centre, and the king of Bantam to the weſt; while the coaſt and effective power almoſt entirely belong to Holland. Thoſe other ſovereigns are deſcended from foreigners alſo; being Arabians, who imported the Mahometan religion into Java, and acquired the dominion of the country; a few inhabitants in the mountains excepted, who have preſerved their independence and their faith, and among other articles that of the tranſmigration of ſouls. According to the Dutch accounts, nothing can be more tyrannic than thoſe Mahometan rulers. The emperor is ſaid to maintain his authority by an army of many thouſand men diſperſed throughout his territories, beſide a numerous female guard about his perſon. Theſe military ladies are trained, it ſeems, to arms, without neglecting thoſe accompliſhments which may occaſion a change in the occupation of ſome among them, rendering them the companions, inſtead of being the attendants, of his Imperial majeſty. This ſingular inſtitution may owe its origin to the facility of obtaining recruits, if it be true, as the ſame accounts pretend, that the number of female births exceeds very conſiderably that of males in Java.

Moſt of the ſlaves are imported into it from Celebes and other eaſtern iſlands. They do not form a corps, or have any bond of union: nor is the general conduct of their owners towards them calculated to aggravate the misfortune of being the property of others. They are not forced to exceſſive labour. They have ſufficient ſuſtenance; but many of the males among them, who had formerly perhaps led an independent life till made captives in their wars, have been found to take offence againſt their maſters upon very ſlight occaſions, and to wreak their vengeance by aſſaſſination. The apprehenſion of ſuch an event is among the motives for preferring at Batavia female ſlaves for every uſe to which they can be applied; ſo that the number purchaſed of them much exceeds that of the other ſex. The ſlaves when determined on revenge often ſwallow, for the purpoſe of acquiring artificial courage, an extraordinary doſe of opium, and ſoon becoming frantic as well as deſperate, not only ſtab the objects of their hate, but ſally forth to attack in like manner every perſon they meet, till ſelf-preſervation renders it neceſſary to deſtroy them. They are ſaid in that ſtate to be *running a muck;* and inſtances of it are not more common among ſlaves than among free natives of the country, who in the anguiſh for loſing their money, effects, and ſometimes their families, at gaming, to which they are violently addicted, or under the preſſure of ſome other paſſion or misfortune, have recourſe to the ſame remedy, with the ſame fatal effects.

In the country round Batavia the eye looks in vain for the common animals and vegetables which it had been daily accuſtomed to meet in Europe. The moſt familiar bird about the houſe of the embaſſador's hoſt was the crown bird, as it was called at Batavia, which was not, however, the *ardea pavonina* of Linnæus, but the *columba criſtata*, having nothing except its creſt in common with the former. The ſame gentleman had al-not only of fear, but alſo of religious veneration, to which offerings are made as to a deity. When a Javaneſe feels himſelf diſeaſed, he will ſometimes build a kind of coop, and fill it with ſuch eatables as he thinks moſt agreeable to the crocodiles. He places the coop upon the bank of the river or canal, in the perfect confidence that, by the means of ſuch offerings, he will get rid of his complaints; and perſuaded, that if any perſon could prove ſo wicked as to take away thoſe viands, ſuch perſon would draw upon himſelf the malady for the cure of which the offering was made. According to Sir George Staunton, Batavia road lies in 6° 10′ ſouth lat. and 106° 51′ eaſt long. from Greenwich.

BATH, a townſhip in Lincoln co. Diſtrict. of Maine, containing 949 inhabitants. It lies on the W. ſide of Kennebeck River about 13 miles from Wiſcaſſet, 60 N. E. from Portland, 32 from Hallowell, 13 from Pownalboro', and 165 N. E. from Boſton. N. lat. 43. 49.—*Morſe.*

Bath, a county of Virginia, about 60 miles in length, and 50 in breadth; bounded E. by the county of Auguſta. It is noted for its medicinal ſprings, called the *Hot* and *Warm* ſprings, near the foot of Jackſon's Mountain, which ſee.—*ib.*

Bath, a thriving town in Berkly co. Virginia, ſituated at the foot of the Warm Spring Mountain. The ſprings in the neighbourhood of this town, although leſs efficacious than the Warm Springs in Bath co. draw upwards of 1000 people here, during ſummer, from various parts of the United States. The water is little more than milk-warm, and weakly impregnated with minerals. The country in the environs is agreeably diverſified with hills and valleys; the ſoil rich, and in good cultivation; 25 miles from Martinſburg, and 269 miles S. W. from Philadelphia.—*ib.*

Bath, a townſhip in Grafton co. N. Hampſhire, containing 493 inhabitants. It lies on the E. bank of Connecticut River 35 miles N. E. by N. from Dartmouth College, and 97 N. W. from Portſmouth.—*ib.*

Bath, or *Port Bath*, an ancient town in Hyde co. N. Carolina, on the N. ſide of Tar River about 24 miles from Pamplico Sound, 61 S. by W. of Edenton, and is the port of entry on Tar River. It contains about 12 houſes, and is rather declining. N. lat. 35. 31. W. long. 77. 15.—*ib.*

Bath, a village in the eaſtern pariſh of St Thomas, in the Iſland of Jamaica, in the W. Indies. It has its riſe and name from a famous hot ſpring in its vicinity, ſaid to be highly efficacious in curing the dry belly-ache. The water is ſulphureous, and flows out of a rocky mountain about a mile diſtant; and is too hot to admit a hand being held in it.—*ib.*

Bath, a village in the co. of Renſſalaer, New-York, pleaſantly ſituated on the eaſt bank of Hudſon river, nearly oppoſite the city of Albany, at the head of ſloop navigation. A mineral ſpring has been diſcovered here, ſaid to poſſeſs valuable qualities; and a commodious bathing-houſe has been erected, at a conſiderable expenſe, containing hot, cold, and ſhower baths. —*ib.*

BAY OF FUNDY, waſhes the ſhores of the Britiſh provinces of New-Brunſwick on the N. and Nova-Scotia on the E. and S. This bay is 12 leagues acroſs, from the Gut of Annapolis to St John's, the principal town of New-Brunſwick. The tides are very rapid in this bay, and riſe at Annapolis Baſin about 30 feet; at the Baſin of Minas, which may be termed the N. arm of this bay, 40 feet; and at the head of Chignecto channel, an arm of this bay, the ſpring tides riſe 60 feet.—*ib.*

BAY OF ISLANDS, lies on the W. ſide of Newfoundland Iſland in the gulf of St Lawrence. This bay is very extenſive, having 3 arms, by which ſeveral rivers empty into it. It has ſeveral iſlands; the chief of which are called Harbor, Pearl, and Tweed. The centre of the bay lies in about 49. 5. N. lat. and 58. 15. W. long. from Greenwich.—*ib.*

BEAR *Graſs Creek*, a ſmall creek on the eaſtern ſide of Ohio River, a few hundred yards N. of the town of Louiſville, in Kentucky. This is the ſpot where the intended canal is propoſed to be cut to the upper ſide of the *Rapids*. From the mouth of the creek, to the upper ſide of the rapids, is not quite 2 miles. This would render the navigation of the Ohio ſafe and eaſy. The country on the ſides of this creek, between Salt River and Kentucky River is beautiful and rich.—*ib.*

BEAUFORT, a ſeaport town in Carteret co. on the N. E. ſide of Core Sound, and diſtrict of Newbern, N. Carolina. It contains about 20 houſes, a court-houſe and gaol, and the county courts are held here. It is 55 miles S. by E. of Newbern, and about 27 from Cape Lookout. N. lat. 34. 47.—*ib.*

Beaufort, the chief town of Beaufort diſtrict, S. Carolina, is ſituated on the iſland of Port Royal, at the mouth of Cooſawhatchie River. The courts which were formerly held here, are now removed to the town of Cooſawhatchie, on the above ſmall river. Beaufort is a little pleaſant town, of about 60 houſes, and 200 inhabitants; who are diſtinguiſhed for their hoſpitality and politeneſs. It has a fine harbor, and bids fair to become a conſiderable town. It uſed to be a ſtation for the Britiſh ſquadron when in their poſſeſſion. Beaufort is ſituated 26 miles from Puriſburg, and 73 from Charleſton, to the S. W. noted for its healthy ſituation. N. lat. 32. 26. W. long. 80. 55.—*ib.*

Beaufort *Diſtrict*, in the lower country of S. Carolina, lies on the ſea coaſt, between Combahee and Savannah rivers. It is 69 miles in length, and 37 in breadth, and is divided into 4 pariſhes, viz. St Helena, St Luke, Prince William, and St Peter, which contain 18,753 inhabitants; of whom only 4346 are whites. The northern part of this district abounds with large foreſts of cypreſs; the lands, however, are fit for raiſing rice, indigo, &c. It ſends 12 repreſentatives and 4 ſenators to the ſtate legiſlature; each pariſh ſending an equal number. Amount of taxes £3,022-2-11 ſter.—*ib.*

BEAVER *Creek*, runs into Lake Erie, at its E. end; about 7 miles S. E. from Fort Erie.—*ib.*

BEAVERS *Town*, at *Tuſkarawas*, lies between Margaret's Creek, an upper N. W. branch of Muſkingum River and the N. branch of that river; at the head of which N. branch there is only a mile's portage to Cayahoga River. Beavers Town lies about 85 miles N. W. from Pittſburg. A little below this a fort was erected in 1764.—*ib.*

BECKET, a townſhip in Berkſhire co. Maſſachuſetts, containing 751 inhabitants. It is 10 miles E. of Stockbridge, and deſerves to have his name tranſmitted with reverence to the lateſt poſterity. Born at Nuremberg, an Imperial city in the circle of Franconia, of a noble family not yet extinct, he had the beſt education which the darkneſs of that age would permit him to have; and the ſtudies to which from his infancy he was moſt addicted, were thoſe of geography, aſtronomy, and navigation. As he advanced in life, he often thought of the exiſtence of the antipodes and of a weſtern continent, of which he was ambitious to make the diſcovery.

Filled with this great idea, in 1459 he paid a viſit to Iſabella, daughter of John I. king of Portugal, at that time regent of the duchy of Burgundy and Flanders; and having informed her of his deſigns, he procured a veſſel, in which, ſailing weſtward, he was the firſt European who is known to have landed on the iſland of Fayal. He there eſtabliſhed in 1460 a colony of Flemings, whoſe deſcendants yet exiſt in the Azores, which were for ſome time called the Flemiſh Iſlands. This circumſtance is proved, not only by the writings of contemporary authors, but alſo by the manuſcripts preſerved in the records of Nuremberg; from the Latin of which the following is tranſlated: "Martin Behem tendered his ſervices to the daughter of John King of Luſitania, who reigned after the death of Philip of Burgundy, ſurnamed the *Good;* and from her procured a ſhip, by means of which, having ſailed beyond all the then known limits of the Weſtern Ocean, he was the firſt who in the memory of man diſcovered the iſland of Fayal, abounding with beech trees, which the people of Luſitania call *faye;* whence it derived its name. After this he diſcovered the neighbouring iſlands, called by one general name the *Azores*, from the multitude of hawks which build their neſts there (for the Luſitanians uſe this term for hawks, and the French too uſe the word *eſſos* or *eſores* in their purſuit of this game); and left colonies of the Flemiſh on them, when they began to be called Flemiſh Iſlands (A)."

After having obtained from the regent a grant of Fayal, and reſided there about twenty years, Behem applied in 1484 (eight years before Columbus's expedition) to John II. king of Portugal, to procure the means of undertaking a great expedition towards the ſouth-weſt. This prince gave him ſome ſhips, with which he diſcovered that part of America which is now called Brazil; and he even ſailed to the Straits of Magellan, or to the country of ſome ſavage tribes whom he called Patagonians, from the extremities of their bodies being covered with a ſkin more like a bear's paws than human hands and feet.

A fact ſo little known, and apparently ſo derogatory to the fame of Columbus, ought not to be admitted without ſufficient proof; but the proofs which have been urged in ſupport of its authenticity are ſuch as cannot be controverted. They are not only the letters of Behem himſelf, written in 1486, and preſerved in the archives of Nuremberg, but likewiſe the public records of that city; in which we read that "Martin Behem, traverſing the Atlantic Ocean for ſeveral years, examined the American iſlands, and diſcovered the ſtrait which bears the name of Magellan before either Chriſtopher Columbus or Magellan ſailed thoſe ſeas; whence he mathematically delineated, on a geographical chart, for the king of Luſitania, the ſituation of the coaſt around every part of that famous and renowned ſtrait long before Magellan thought of his expedition."

This wonderful diſcovery has not eſcaped the notice of contemporary writers. The following paſſage is tranſlated from the Latin chronicle of Hartman Schedl: "In the year 1485, John II. king of Portugal, a man of a magnanimous ſpirit, furniſhed ſome galleys with proviſions, and ſent them to the ſouthward, beyond the Straits of Gibraltar. He gave the command of this ſquadron to James Canus, a Portugueſe, and Martin Behem, a German of Nuremberg in Upper Germany, deſcended of the family of Bonna: a man very well acquainted with the ſituation of the globe; bleſſed with a conſtitution able to bear the fatigues of the ſea; and who, by actual experiments and long ſailing, had made himſelf perfectly maſter with regard to the longitudes and latitudes of Ptolemy in the weſt. Theſe two, by the bounty of Heaven, coaſting along the Southern Ocean, and having croſſed the equator, got into the other hemiſphere, where, facing to the eaſtward, their ſhadows projected towards the ſouth and right hand. Thus, by their induſtry, they have opened to us another world hitherto unknown, and for many years attempted by none but the Genoeſe, and by them in vain. Having finiſhed this cruize in the ſpace of 26 months, they returned to Portugal with the loſs of many of their ſeamen by the violence of the climate."

Beſides this evidence of the firſt diſcovery of America having been made by Behem, we find the following particulars in the remarks made by Petrus Mateus on the canon law, two years before the expedition of Columbus: "*Primæ navigationes*, &c. The firſt Chriſtian voyages to the newly diſcovered iſlands became frequent under the reign of Henry, ſon of John, king of Luſitania. After his death Alphonſus V. proſecuted the deſign; and John, who ſucceeded him, followed the plan of Alphonſus, by the aſſiſtance of Martin Bohem, a very ſkilful navigator; ſo that in a ſhort time the name of Luſitania became famous over the whole world." Cellarius, one of the moſt learned men of his age, ſays expreſsly, "*Behaimeus non modo*, &c. Bœhm did not think it enough to ſurvey the iſland of Fayal, which he firſt diſcovered, or the other adjacent iſlands which the Luſitanians call *Azores*, and we, after the example of Bœhm's companions, call *Flemiſh* iſlands, but advanced ſtill farther and farther ſouth, until he arrived at the remoteſt ſtrait, through which Ferdinand Magellan, following

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(A) Although this record is contrary to the generally received opinion, that the Azores were diſcovered by Gonſalva Velho, a Portugueſe, yet its authenticity ſeems unqueſtionable. It is confirmed not only by ſeveral contemporary writers, and by Wagenſeil, one of the moſt learned men of the laſt century, but likewiſe by a note written on parchment in the German language, and ſent from Nuremberg, a few years ago, to M. Otto, who was then inveſtigating the diſcovery of America. The note contained, with other things, the following facts: "Martin Beham, Eſq; ſon of Mr Martin Beham of Scoperin, lived in the reign of John II. king of Portugal, in an iſland which he diſcovered, and called the iſland of *Fayal*, one of the Azores, lying in the Weſtern Ocean."

ſmalleſt degree invalidate the poſitive evidence which we have urged for the Chevalier Behem's being the real diſcoverer of the new world; for it would ſurely be very abſurd to oppoſe the *difficulty of aſſigning motives* for *certain* actions performed at a remote period, to the *reality* of *other* actions for which we have the teſtimony of a cloud of contemporary witneſſes. Suppoſing it were true, therefore, that Behem had left behind him no writing claiming to himſelf the diſcovery of any part of the continent of America, the only inference which could be drawn from his ſilence would be, either that he was a man of great modeſty, or that his mind was intent only on the acquiſition of knowledge to himſelf, without feeling the uſual impulſe to communicate that knowledge to others. But it is not true that he has left behind him no claim of this diſcovery to himſelf. The letters to which we have appealed, and which are preſerved in the archives of Nuremberg, together with the globe and map, which he certainly made, furniſh as complete a confirmation of his claim as could have been furniſhed by the moſt elegant account of his voyages.

For the ſilence of the Portugueſe, many reaſons might be aſſigned. The diſcoveries of Columbus were made ſo much farther north than thoſe of Behem, that, in an age when geographical knowledge was ſo very limited, both Spaniards and Portugueſe might very naturally believe that the country diſcovered by the former of theſe navigators had no connection with that diſcovered by the latter. At any rate, the Portugueſe, whoſe diſcoveries proceeded from avarice, were ſatisfied with ſcraping together gold wherever they could find it; and finding it in Africa, they thought not of ſearching for it in a more diſtant region, till the ſucceſs of the Spaniards ſhewed them their miſtake.

One thing more is worthy of attention. The long ſtay of Columbus at Madeira makes his interview with Behem more than probable. It is impoſſible that he ſhould have neglected ſeeing a man ſo intereſting, and who could give him every kind of information for the execution of the plan which he had formed. The mariners who accompanied the Chevalier Behem might alſo have ſpread reports at Madeira and the Azores concerning the diſcovery of which they had been witneſſes. What ought to confirm us in this is, that Mariana ſays himſelf (book xxvi. chap. iii.), that a certain veſſel going to Africa, was thrown by a gale of wind upon certain unknown lands; and that the ſailors at their return to Madeira had communicated to Chriſtopher Columbus the circumſtances of their voyage. All authors agree that this learned man had ſome information reſpecting the weſtern ſhores; but they ſpeak in a very vague manner. The expedition of the Chevalier Behem explains the myſtery (B).

BEHRING's *Bay*, on the N. W. coaſt of N. America, is ſeparated from Admiralty Bay, on the northward, by a point of land; and lies N. W. from Croſs Sound.—*Morse.*

BEHRING's *Straits*, ſeparate Aſia from America, are ſo called from the Ruſſian navigator, Capt. Behring, who with Iſhirikow, ſailed from Kamptſchatka, in Siberia, on the Aſiatic coaſt, in queſt of the New World, in a quarter where it had, perhaps, never been approached. They both diſcovered land within a few degrees of the N. W. coaſt of America. But the more recent diſcoveries of Capt. Cook, and his ſucceſſor, Clarke, have confirmed the near approximation of the two continents. Cape Prince of Wales is the moſt weſterly point of the American continent, hitherto known. It is ſituated in N. lat. 65. 46. E. long. 191. 45. and is 39 miles diſtant from the eaſtern coaſt of Aſia.

The ſea, from the S. of Behring's Straits, to the creſcent of iſles between Aſia and America, is very ſhallow. It deepens from theſe ſtraits (as the Britiſh ſeas do from Dover) till ſoundings are loſt in the Pacific Ocean; but that does not take place but to the S. of the iſles. Between them and the ſtraits is an increaſe from 12 to 54 fathoms, except only off St Thaddeus Noſs, where there is a channel of greater depth. From the volcanic diſpoſition, it has been judged probable, not only that there was a ſeparation of the continents at theſe ſtraits, but that the whole ſpace from the iſles to that ſmall opening had once been dry land; and that the fury of the watery element actuated by that of fire, had, in very remote times, ſubverted and overwhelmed the tract, and left the iſlands to ſerve as monumental fragments.

The famous Japaneſe map places ſome iſlands ſeemingly within theſe ſtraits, on which is beſtowed the title of *Ya Zue*, or the kingdom of the dwarfs. This gives ſome reaſon to ſuppoſe that America was not unknown to the Japaneſe; and that they had, as is mentioned by Kæmpfer, and Charlevoix, made voyages of diſcovery; and, according to the laſt, actually wintered upon the continent, where probably meeting with the Eſquimaux, they might, in compariſon of themſelves, and juſtly, diſtinguiſh them by the name of dwarfs.—*ib.*

BEKIA, or *Becouya*, or *Boquio*, a ſmall Britiſh iſland among the Granadillas; 55 miles N. E. of Granada, and 65 leagues from Barbadoes. It was called Little Martinico by the French, and has a ſafe harbour from all winds; but no freſh water. It is only frequented by thoſe who catch turtle. The ſoil produces wild cotton, and plenty of water melons.—*ib.*

BELCHER, a townſhip in Hampſhire co. Maſſachuſetts, containing 1485 inhabitants, who ſubſiſt chiefly by farming. It lies 12 miles E. of Hadley, and 85 W. of Boſton.—*ib.*

BELFAST, a townſhip and bay in Hancock co. Diſtrict of Maine, both ſituated in what is called the Waldo Patent, at the mouth of Penobſcot River and on its weſtern ſide; 38 miles N. E. by E. from Hallowell, and 246 N. E. from Boſton. The town contains 245 inhabitants. The Bay, on the N. weſtern part of which the town ſtands, runs up into the land by three ſhort arms. Iſleſborough Iſland lies in the middle of it, and forms two channels leading to the mouth of Penobſcot river.—*ib.*

(B) For the greater part of this memoir we are indebted to M. Otto's paper on the diſcovery of America, publiſhed firſt in the ſecond volume of the American Tranſactions, and afterwards by Nicholſon in N° II. and III. of his Journal.

BELLAIRE, a poſt-town near the centre of Harford co. Maryland, and the chief of the county. It contains a court-houſe and gaol, and is thinly inhabited; diſtant from Harford, 6 miles, N. W; 22 N. E. from Baltimore, and 86 W. S. W. from Philadelphia. —*Morse.*

BELLINGHAM, a ſmall farming townſhip in Norfolk co. Maſſachuſetts, containing 735 inhabitants, 20 miles northerly from Providence, and 34 ſoutherly from Boſton.—*ib.*

BELLS *Mill*, a ſettlement in N. Carolina, near the Moravian ſettlements, at the ſource of Deep river the N. weſtern-moſt branch of the N. W. branch of Cape Fear, and about 50 miles W. of Hillſborough.—*ib.*

BELPRE, a poſt-town and ſmall ſettlement in the territory N. W. of the Ohio, on the N. W. bank of Ohio river between the Hockhocking and Muſkingum rivers and oppoſite the mouth of the Little Kanhaway; about 14 miles below Marietta, and 480 S. W. by W. from Philadelphia.—*ib.*

BELVIDERE, a new townſhip in Franklin co. Vermont.——Alſo a village in New-Jerſey, in Suſſex co. ſituated on Delaware river at the mouth of Pequeſt river and 11 miles above Eaſton, in Pennſylvania.—*ib.*

BENNINGTON, a county in the S. W. corner of Vermont, having Windham co. on the E. and the ſtate of N. York on the W; into which ſtate it ſends Batten Kill and Hooſack rivers, which both riſe here, and fall into Hudſon river 14 miles apart: Rutland co. lies on the N. and the ſtate of Maſſachuſetts on the S. It contains 19 townſhips, of which Bennington and Mancheſter are the chief. It has 12,254 inhabitants, including 16 ſlaves. The mountains here furniſh iron ore in abundance, and employ already, a furnace and two forges.—*ib.*

BENNINGTON, the ſhire town of the above county, and the largeſt town in the ſtate of Vermont, having about 160 houſes, in the compact part of the town, is ſituated at the foot of the Great Mountain, near the S. W. corner of the ſtate, 24 miles eaſterly from the junction of Hudſon and Mohawk rivers, and about 52 from the S. end of Lake Champlain, at the confluence of the E. and S. bays; and lies 55 miles from Rutland; 202 miles N. eaſterly from New-York; and 300 in the ſame direction from Philadelphia. N. lat. 42. 42. W. long. 74. 10. Bennington has ſeveral elegant buildings. Its public edifices are a congregational church, ſtate houſe and gaol. It is the oldeſt town in the ſtate, having been firſt ſettled in 1764, and is in a flouriſhing condition, containing 2,400 inhabitants. Within the townſhip is Mount Anthony, which riſes very high in a conical form.

Two famous battles were fought in or near this town, in one day, Aug. 16, 1777, in which Col. Stark gained great fame. The Britiſh loſt 4 braſs field pieces, and other military ſtores; and beſides thoſe ſlain, 700 were taken priſoners. The killed and wounded of the Americans were about 100 men. This defeat contributed, in a great meaſure, to the ſubſequent ſurrender of Gen. Burgoyne's army.—*ib.*

BENSON, the N. weſternmoſt townſhip in Rutland co. Vermont, is ſituated on the E. ſide of Lake Champlain; 57 miles N. N. W. of Bennington, and has 658 inhabitants. Hubberton river paſſes through Benſon in its way to Eaſt Bay. Cockburne's Creek, which feeds the ſame bay, riſes here.—*ib.*

Bereans.

BEREANS, in ancient church hiſtory, the inhabitants of Berea. They are highly commended in Scripture for their ready reception of the goſpel, upon a fair and impartial examination of its agreement with the Old Teſtament prophecies. Sopater, a Berean, attended the apoſtle Paul to Aſia. Acts xvii. 10—13. and xx. 4.

BEREANS, in modern church hiſtory, a ſect of Proteſtant diſſenters from the church of Scotland, who take their title from, and profeſs to follow, the example of the ancient Bereans, in building their ſyſtem of faith and practice upon the Scriptures alone, without regard to any human authority whatever.

Doctrines.

The Bereans agree with the great majority of Chriſtians, both Proteſtants and Catholics, reſpecting the doctrine of the Trinity, which they hold as a fundamental article of the Chriſtian faith; and they alſo agree in a great meaſure with the *profeſſed* principles of both our eſtabliſhed churches reſpecting predeſtination and election, though they allege that theſe doctrines are not conſiſtently taught in either church. But they differ from the majority of all ſects of Chriſtians in various other important particulars. Such as,

1. Reſpecting our knowledge of the Deity. Upon this ſubject, they ſay, that the majority of profeſſed Chriſtians ſtumble at the very threſhold of revelation; and, by admitting the doctrine of natural religion, natural conſcience, natural notices, &c. not founded upon revelation, or derived from it by tradition, they give up the cauſe of Chriſtianity at once to the infidels; who may juſtly argue, as Mr Paine in fact does in his Age of Reaſon, that there is no occaſion for any revelation or word of God, if man can diſcover his nature and perfections from his works alone. But this, the Bereans argue, is beyond the natural powers of human reaſon; and therefore our knowledge of God is from revelation alone; and that without revelation man would never have entertained an idea of his exiſtence.

2. With regard to faith in Chriſt, and aſſurance of ſalvation through his merits, they differ from almoſt all other ſects whatſoever. Theſe they reckon *inſeparable*, or rather the *ſame*; becauſe, they argue, God hath expreſsly declared, "He that believeth ſhall be ſaved;" and therefore it is not only abſurd, but impious, and in a manner calling God a liar, for a man to ſay, "*I believe* the Goſpel, but *have doubts* nevertheleſs of my own ſalvation." With regard to the various diſtinctions and definitions that have been given of different kinds of faith, they argue, that "there is nothing incomprehenſible or obſcure in the meaning of this word as uſed in Scripture; but that as faith, when applied to human teſtimony, ſignifies neither more nor leſs than the mere ſimple belief of that teſtimony as true, upon the authority of the teſtifier; ſo, when applied to the teſtimony of God, it ſignifies preciſely the belief of his teſtimony, and reſting upon his veracity alone, without any kind of collateral ſupport from concurrence of any other evidence or teſtimony whatever." And they inſiſt, that as this faith is the gift of God alone, ſo the perſon to whom it is given is as conſcious of poſſeſſing it, as the being to whom God gives life is of being alive; and therefore he entertains no doubts either of this faith or his conſequent ſalvation through the merits of Chriſt,

who died and roſe again for that purpoſe. In a word, they argue, that the Goſpel would not be what it is held forth to be, " glad tidings of great joy," if it did not bring full perſonal aſſurance of eternal ſalvation to the believer: which aſſurance, they inſiſt, " is the preſent infallible privilege and portion of every individual believer of the Goſpel." Theſe definitions of faith, and its inſeparable concomitant aſſurance, they prove by a variety of texts, which our room permits us not to quote.

3. Conſiſtently with the above definition of faith, they ſay, that the ſin againſt the Holy Ghoſt, which has alarmed and puzzled ſo many in all ages, is nothing elſe but *unbelief;* and that the expreſſion, that " it ſhall not be forgiven, neither in *this world* nor that which is to come," means only, that a perſon dying in infidelity would not be forgiven, neither under the former diſpenſation by Moſes (the then *preſent* diſpenſation, kingdom, or government of God), nor under the Goſpel diſpenſation, which, in reſpect of the Moſaic, was a kind of future world or kingdom to come.

4. The Bereans interpret a great part of the Old Teſtament prophecies, and in particular the whole of the Pſalms, excepting ſuch as are merely hiſtorical or lauditory, to be typical or prophetical of Jeſus Chriſt, his ſufferings, atonement, mediation and kingdom: and they eſteem it a groſs perverſion of theſe Pſalms and prophecies to apply them to the experiences of private Chriſtians. In proof of this, they not only urge the words of the apoſtle, that " no prophecy is of any private interpretation," but they inſiſt that the whole of the quotations from the ancient prophecies in the New Teſtament, and particularly thoſe from the Pſalms, are expreſsly applied to Chriſt. In this opinion many other claſſes of Proteſtants agree with them.

5. Of the abſolute all-ſuperintending ſovereignty of the Almighty, the Bereans entertain the higheſt ideas, as well as of the uninterrupted exertion thereof over all works in heaven, earth, and hell, however unſearchable by his creatures. " A God without election (they argue), or choice in all his works, is a god without exiſtence—a mere idol—a non-entity. And to deny God's election, purpoſe, and expreſs will in all his works, is to make him inferior to ourſelves." For farther particulars reſpecting the Berean doctrines, we muſt refer the reader to the works of Meſſrs Barclay, Nicol, Brookſbank, &c.

Origin. The Bereans firſt aſſembled as a ſeparate ſociety of Chriſtians in the city of Edinburgh in autumn 1773, and ſoon after in the pariſh of Fettercairn. The opponents of the Berean doctrines allege, that this new ſyſtem of faith would never have been heard of, had not Mr Barclay, the founder of it, been diſappointed of a ſettlement in the church of Scotland. A reſpectable clergyman of the eſtabliſhed church has even hinted ſomething to this purpoſe in Sir John Sinclair's Statiſtical Account, Vol. IX. p. 599. But the Bereans, in anſwer to this charge, appeal not only to Mr Barclay's doctrine, uniformly preached in the church of Fettercairn, and many other places in that neighbourhood, for fourteen years before that benefice became vacant; but likewiſe to two different treatiſes, containing the ſame doctrines, publiſhed by him about ten or twelve years before that period. They admit, indeed, that, previous to May 1773, when the general aſſembly, by ſuſtaining the king's preſentation in favour of Mr Foote, excluded Mr Barclay from ſucceeding to the church of Fettercairn (notwithſtanding the almoſt unanimous deſire of the pariſhioners), the Bereans had not left the eſtabliſhed church, or attempted to erect themſelves into a diſtinct ſociety; but they add, that this was by no means neceſſary on their part, until by the aſſembly's deciſion they were in danger of being not only deprived of his inſtructions, but of being ſcattered as ſheep without a ſhepherd. And they add, that it was Mr Barclay's open and public avowal, both from the pulpit and the preſs, of thoſe peculiar ſentiments which now diſtinguiſh the Bereans, that was the firſt and principal, if not the only, cauſe of the oppoſition ſet on foot againſt his ſettlement in Fettercairn.

Practice. Having thus given a conciſe view of the origin and diſtinguiſhing doctrines of Bereaniſm, it only remains to mention a few particulars relative to the practice of the Bereans as a Chriſtian ſociety. Infant baptiſm they conſider as a divine ordinance inſtituted in the room of circumciſion; and they think it abſurd to ſuppoſe that infants, who all agree are admiſſible to the kingdom of God in heaven, ſhould neverthelefs be incapable of being admitted into His viſible church on earth. They commemorate the Lord's ſupper in general once a month; but as the words of the inſtitution fix no particular period, they ſometimes celebrate it oftener, and ſometimes at more diſtant periods, as may ſuit their general convenience. In obſerving this ordinance, they follow the primitive apoſtolic plan, without any previous days of faſting or preparation; as they apprehend that ſuch human inſtitutions only tend to make an idol of the ordinance, and to lead people to entertain erroneous ideas of its ſuperior ſolemnity and importance. Equal and univerſal holineſs in all manner of converſation, they recommend at all times, as well as at the table of the Lord. They meet every Lord's day for the purpoſe of preaching, praying, and exhortation to love and good works. With regard to the admiſſion and excluſion of members, their method is very ſimple. When any perſon, after hearing the Berean doctrines, profeſſes his belief and aſſurance of the truths of the Goſpel, and deſires to be admitted into their communion, he is cheerfully received upon his profeſſion, whatever may have been his former manner of life. But if ſuch an one ſhould afterwards draw back from his good profeſſion or practice, they firſt admoniſh him; and if that has no effect, they leave him to himſelf. They do not think that they have any power to deliver up a backſliding brother to Satan. That text and other ſimilar paſſages, ſuch as, " Whatſoever ye ſhall bind on earth ſhall be bound in heaven," &c. they conſider as reſtricted to the apoſtles and to the inſpired teſtimony alone, and not to be extended to any church on earth, or any number of churches or of Chriſtians, whether deciding by a majority of votes or by unanimous voices. Neither do they think themſelves authoriſed, as a Chriſtian church, to enquire into each others political opinions, any more than to examine into each others notions of philoſophy. They both recommend and practiſe, as Chriſtian duties, ſubmiſſion to lawful authority; but they do not think that a man, by becoming a Chriſtian, or joining their ſociety, is under any obligation, by the rules of the Goſpel, to renounce his rights of private judgment upon matters of public or private importance. Upon all men who have written on the ſubject. His biographical powers appear in his *Biographia Literaria;* and in all his works are ſufficient proofs of his claſſical learning, and that the Italian, French, German, and Dutch languages, were familiar to him. He poſſeſſed likewiſe a very conſiderable degree of mathematical ſcience, which he acquired in the courſe of his military ſtudies; and to thoſe more ſolid attainments he is ſaid to have added no ſmall ſkill in the fine arts of painting and muſic. This eminent man, who, for the variety and promptitude of his knowledge, has been compared to the Admirable Crichton, died on the 3d of April 1791.

BERKLEY, a townſhip in Briſtol co. Maſſachuſetts, containing 850 inhabitants; 50 miles ſouthward of Boſton.—*Morse.*

Berkley, the name both of a county and town, in Charleſton Diſtrict, S. Carolina, lying near Cooper and Aſhley rivers. In the cenſus of 1791, it was called St John's Pariſh, in Berkley co. and contained 752 free perſons, and 5170 ſlaves.—*ib.*

Berkley *Co.* in Virginia, lies W. of the Blue Ridge, N. of Frederick co. and ſeparated from the ſtate of Maryland, on the N. and E. by Potowmack river. This fertile county, about 40 miles long and 20 broad, has 16,781 free inhabitants and 2932 ſlaves. Martinſburg is its chief town.—*ib.*

Berkley's *Sound,* on the N. W. coaſt of N. America, lies on the eaſtern ſide of Quadras Iſles. The land on its eaſtern ſide is oppoſite Cape Flattery, and forms the N. ſide of the Straits de Fuca.—*ib.*

BERK's *Co.* in Pennſylvania, has Northampton co. on the N. E.; Northumberland on the N. W.; part of Luzern on the N.; Dauphin and Lancaſter counties S. W. and Cheſter and Montgomery S. E. It is watered by Schuylkill River and is 53 miles long and near 29 broad, containing 1,030,400 acres. Here iron ore and coal are found in plenty, which ſupply ſeveral iron works. The northern parts are rough and hilly. Berks contains 30,179 inhabitants, of whom 65 only are ſlaves. It has 29 townſhips, of which Reading is the chief.—*ib.*

BERKSHIRE *Co.* in Maſſachuſetts, is bounded W. by New-York ſtate; S. by the ſtate of Connecticut; E. by Hampſhire co. and N. by the ſtate of Vermont. It thus runs the whole extent of the ſtate from N. to S. and contains twenty-ſix townſhips; the chief of which are Stockbridge, Lenox, Great Barrington, Williamſtown, and Pittsfield; and the number of inhabitants 30,291. White and clouded marble is found in ſeveral towns, in the rough and hilly parts of this county.

In February, 1796, the legiſlature paſſed an act to eſtabliſh a college in Williamſtown, by the name of Williams College.—*ib.*

Berkshire, a newly ſettled townſhip, in Franklin co. Vermont.—*ib.*

BERLIN, a neat and flouriſhing town of York co. Pennſylvania, containing about 100 houſes. It is regularly laid out, on the S. W. ſide of Conewago Creek, 13 miles weſterly of Yorktown, and 101 W. of Philadelphia. N. lat. 39. 56.—*ib.*

Berlin, a townſhip in Orange co. Vermont, on Dog River a branch of Onion River from the S.; which laſt ſeparates Berlin from Montpelier, on the N. N. W. Berlin contains 134 inhabitants, and is about 94 miles N. eaſterly from Bennington.—*ib.*

Berlin, a townſhip in Hartford co. Connecticut, 12 miles S. S. W. of Hartford, 42 N. W. of New-London; and 26 N. N. E. of New-Haven.—*ib.*

Berlin, a townſhip in Worceſter co. Maſſachuſetts, containing 512 inhabitants; 34 miles W. of Boſton, and 15 N. E. of Worceſter. Hops have been cultivated here lately, and promiſed to be a valuable article of huſbandry.—*ib.*

Berlin, in Somerſet co. formerly in that of Bedford, Pennſylvania, lies on a branch of Stony Creek, a ſouth water of Conemaugh River on the W. ſide of the Alleghany Mountain; 25 miles weſtward of Bedford; 23 N. W. of Fort Cumberland, in Virginia, and 200 W. of Philadelphia. Stone Creek, the chief ſource of Kiſkeminitas river riſes N. N. E. of Berlin. N. lat. 39. 54.—*ib.*

BERMUDA HUNDRED, or *City Point,* as it is ſometimes called, is a port of entry and poſt town, in Cheſterfield co. Virginia, ſituated on the point of the peninſula, formed by the confluence of the Appamattox with James River, 36 miles weſterly from Williamſburg, 64 from Point Comfort, in Cheſapeak Bay, and 315 S. W. by S. from Philadelphia. City Point, from which it is named, lies on the ſouthern bank of James River, 4 miles S. S. W. from this town. The exports from this place, chiefly collected at Richmond, 20 miles above it, amounted in 1794, to the value of 773,549, dollars; and from the 1ſt of October, to 1ſt December 1795, were as follow: 15 kegs of butter, 578 bbls. ſuperfine flour, 101 half do. 789 fine do. 393 lbs. indigo, 10 tons pig iron, 100 lbs. ſaſſafras, 80,320 hhd. ſtaves, 66,300 bbl. ſtaves, 1,819 hhds. tobacco, and 3 kegs manufactured do.—Total exports 90,859 dollars, 45 cents. There are about 40 houſes here, including ſome warehouſes. It trades chiefly with the W. Indies, and the different ſtates. City Point, in James River, lies in N. lat. 37. 16. W. long. 77. 31½.—*ib.*

BERNARD's *Bay,* lies on the N. W. ſide of the gulf of Mexico. The paſſage into it, between ſeveral iſlands, is called Paſco de Cavallo.—*ib.*

BERNARDSTOWN, in Somerſet co. New-Jerſey, contains 2377 inhabitants, including 93 ſlaves.

Alſo the name of a townſhip in Hampſhire co. Maſſachuſetts, containing 691 inhabitants; diſtant 110 miles weſtward from Boſton.—*ib.*

BERNE, a townſhip in Albany co. New-York. By the ſtate cenſus of 1796, it appears there are 447 of the inhabitants who are electors.—*ib.*

BERNOULLI (John), a celebrated mathematician, was born at Baſil the 7th of Auguſt 1667. His father intended him for trade; but his own inclination was at firſt for the belles lettres, which, however, like his brother James, whoſe life is given in the Encyclopædia, he left for mathematics. He laboured with his brother to diſcover the method uſed by Leibnitz, in his eſſays on the differential calculus, and gave the firſt principles of the integral calculus. Our author, with Meſſrs Huygens and Leibnitz, is ſaid to have been the firſt who gave the ſolution of the problem propoſed by James Bernoulli, concerning the catenary, or curve formed by a chain ſuſpended by its two extremities. But for more on this ſubject, ſee Arch in this Supplement.

John Bernoulli had the degree of doctor of phyſic at Baſil, and two years afterward was named profeſſor of mathematics in the univerſity of Groningen. It was here that he diſcovered the mercurial phoſphorus, or luminous barometer; and where he reſolved the problem propoſed by his brother concerning iſoperimetricals.

On the death of his brother James, the profeſſor at Baſil, our author returned to his native country, againſt the preſſing invitations of the magiſtrates of Utrecht to come to that city, and of the univerſity of Groningen, who wiſhed to retain him. The Academic Senate of Baſil ſoon appointed him to ſucceed his brother, without aſſembling competitors, and contrary to the eſtabliſhed practice; an appointment which he held during his whole life.

In 1714 was publiſhed his treatiſe on the management of ſhips; and in 1730 his memoir on the elliptical figure of the planets gained the prize of the Academy of Sciences. The ſame Academy alſo divided the prize for their queſtion concerning the inclination of the planetary orbits, between our author and his ſon Daniel. See Bernoulli (Daniel), *Encycl.*

John Bernoulli was a member of moſt of the academies of Europe, and received as a foreign aſſociate of that of Paris in 1699. After a long life ſpent in conſtant ſtudy and improvement of all the branches of the mathematics, he died full of honours, the 1ſt of January 1748, in the 81ſt year of his age. Of five ſons which he had, three purſued the ſame ſciences with himſelf. One of theſe died before him; the two others, Nicolas and Daniel, he lived to ſee become eminent, and much reſpected in the ſame ſciences.

The writings of this great man were diſperſed through the periodical memoirs of ſeveral academies, as well as in many ſeparate treatiſes. And the whole of them were carefully collected and publiſhed at Lauſanne and Geneva, 1742, in 4 vols. 4to. He was of undoubted eminence; but even in ſcience he was a haſty man, and certainly envious of the fame of Newton.

BERTIE, a maritime co. in N. Carolina, in Edenton diſtrict, with the Roanoke its S. boundary, and Albemarle Sound on the E. In it is ſituated the ancient Indian tower of Tuſcarora. It contains 12,606 ſouls, of which number 5141 are ſlaves.—*Morſe.*

BERWICK, or *Abbotſtown*, a neat town in York co. Pennſylvania, at the head of Conewago Creek, 13 miles weſtward of York, 26 S. S. W. of Harriſburg, and 103 W. by S. of Philadelphia. The town is regularly laid out, and contains about 100 houſes, a German Lutheran, and a Calviniſt church. N. lat. 39. 54.—*ib.*

Berwick, or *New-Berwick*, a ſmall town of Northumberland co. Pennſylvania, on the N. weſtern ſide of the E. branch of Suſquehannah River oppoſite Neſcopeck Falls, and Neſcopeck Creek, 32½ miles N. E. from Northumberland and Sunbury, at the junction of the E. with the W. branch of Suſquehannah, and 160 N. W. of Philadelphia. N. lat. 41. 3.—*ib.*

Berwick, a townſhip in York co. Diſtrict of Maine, containing 3894 inhabitants. It has an incorporated academy, and lies on the E. ſide of Salmon Fall River, 7 miles N. W. of York, and 86 E. of N. from Boſton.—*ib.*

BETELGEUSE, a fixed ſtar of the firſt magnitude, in the right ſhoulder of Orion.

BETHABARA, the firſt ſettlement of the Moravians in the lands of Wachovia, in N. Carolina, begun in 1753; 6 miles N. of Salem, and 183 W. of Halifax, in N. lat. 36. 9. It is ſituated on the W. ſide of Graſſy Creek, which unites with the Gargales, and ſeveral others, and falls into the Yadkin. It contains a church of the United Brethren, and about 50 dwelling houſes.—*Morſe.*

BETHANY, or *Bethania*, a Moravian ſettlement and poſt town, in the lands of Wachovia, in N. Carolina, begun in 1760; 9 miles N. W. of Salem, 4 N. W. of Bethabara, and 568 S. W. by S. of Philadelphia. It contains about 60 houſes, and a church, built on a regular plan.—*ib.*

BETHEL, a ſmall Moravian ſettlement on Swetara River in Pennſylvania, 12 miles from Mount Joy.——A townſhip in Dauphin county.—*ib.*

Bethel, a townſhip in Windſor co. Vermont, containing 473 inhabitants; N. N. W. of, and bounded by Stockbridge, and about 67 miles N. N. eaſterly of Bennington. It gives riſe to a ſmall branch of White River.—*ib.*

Bethel, a townſhip in Delaware co. Pennſylvania.—*ib.*

Bethel (Mount) a townſhip in Northampton county, Pennſylvania.

BETHLEHEM, a town in Albany co. New-York, very fruitful in paſtures, and has large quantities of excellent butter. By the ſtate cenſus of 1796, 388 of the inhabitants are electors.—*ib.*

Bethlehem, a townſhip in Berkſhire co. Maſſachuſetts, having 261 inhabitants. It lies about 10 miles S. of E. from Stockbridge, 10 from Lenox, and 130 from Boſton. It borders on Tyringham and Loudon.—*ib.*

Bethlehem, a townſhip in Hunterdon co. New-Jerſey, ſituated at the head of the S. branch of Raritan River. It contains 1335 inhabitants, including 31 ſlaves. Turf for firing is found here.—*ib.*

Bethlehem, a townſhip in Litchfield co. Connecticut, joins Litchfield on the N. and Woodbury on the S.—*ib.*

Bethlehem, a poſt town in Northampton co. Pennſylvania, is a celebrated ſettlement of the Moravians, or *United Brethren*, of the Proteſtant Epiſcopal church, as they term themſelves. It is ſituated on Lehigh River a weſtern branch of the Delaware, 53 miles northerly from Philadelphia, and 18 ſoutherly from the *Wind Gap*. The town ſtands partly on the lower banks of the Manakes, a fine creek, which affords trout and other fiſh. The ſituation is healthful and pleaſant, and in ſummer is frequented by gentry from different parts. In 1787, there were 60 dwelling houſes of ſtone, well built, and 600 inhabitants. Beſides the meeting-houſe, are 3 other public buildings, large and ſpacious; one for the ſingle brethren, one for the ſingle ſiſters, and the other for the widows. The literary eſtabliſhments, as well as the religious regulations, here, deſerve notice.—In a houſe adjoining to the church, is a ſchool for females; and ſince 1787, a boarding ſchool for young ladies, who are ſent here from different parts, and are inſtructed in reading and writing (in the Engliſh and German tongues) grammar, arithmetic, geography, needle work, muſic, &c. The miniſter of the place has the direction of this as well as of the boys ſchool, which is kept in a ſeparate houſe, where they are initiated in the fundamental branches of literature. Theſe ſchools, eſpecially that for the young ladies, are deſervedly in very high repute; and ſcholars, more than can be accommodated, are offered from all parts of the United States.

There is at the lower part of the town a machine, of ſimple conſtruction, which raiſes the water, from a ſpring, into a reſervoir, to the height of 100 feet; whence it is conducted by pipes into the ſeveral ſtreets of the town.

There is a genteel tavern at the N. end of the town, the profit ariſing from which, belongs to the ſociety. There is alſo a ſtore, with a general aſſortment of goods, an apothecary's ſhop, a large tan-yard, a currier's, and a dyer's ſhop, a griſt-mill, a fulling-mill, an oil-mill, and a ſaw-mill, and on the banks of the Lehigh, a brewery. N. lat. 40. 37. W. long. 75. 14. —*Morſe.*

BEVERLY, a townſhip and poſt town in Eſſex co. Maſſachuſetts, containing 3290 inhabitants, is ſeparated from Salem by a handſome bridge, and is about 20 miles E. of N. of Boſton, and 22 S. W. of Newburyport. It has two pariſhes. In the pariſh next the harbor, are a number of handſome houſes, exhibiting the cheering rewards of enterpriſe and induſtry, and the inhabitants are devoted to the fiſhery and other branches of navigation. In the other part of the town, which is chiefly agricultural, is a cotton manufactory. The bridge, mentioned before, is 1500 feet in length, erected in 1788, and connects this town with Salem. It has a draw for veſſels.—*ib.*

BEVERLY's *Manor,* or *Iriſh Tract,* in Virginia, is a tract of land, in N. lat. 38. 10. at the head of Maſſanuten's River, a weſtern branch of the Shenandoah, which riſes here by three branches, viz. Middle River, Lewis and Chriſtian Creeks. It lies between the Blue, and the North Ridge. The road from Yadkin River, through Virginia to Philadelphia, paſſes through here. —*ib.*

BEZOUT (Stephen), a celebrated French mathematician, member of the Academies of Sciences and the Marine, and examiner of the guards of the marine and of the eleves of artillery, was born at Nemours the 31ſt of March 1730. In the courſe of his ſtudies he met with ſome books of geometry, which gave him a taſte for that ſcience; and the Eloges of Fontenelle, ſhewed him the honours attendant on talents and the love of the ſciences. His father in vain oppoſed the ſtrong attachment of young Bezout to the mathematical ſciences. April 8, 1758, he was named adjoint-mechanician in the French Academy of Sciences; having before that ſent them two ingenious memoirs on the integral calculus, and given other proofs of his proficiency in mathematics. In 1763, he was named to the new office of examiner to the marine, and appointed to compoſe a ſyſtem of mathematics for their uſe; and in 1768, on the death of M. Camus, he ſucceeded as examiner of the artillery eleves.

Bezout fixed his attention more particularly to the reſolution of algebraic equations; and he firſt found out the ſolution of a particular claſs of equations of all degrees. This method, different from all former ones, was general for the cubic and biquadratic equations, and juſt became particular only at thoſe of the 5th degree. Upon this work our author laboured from 1762 till 1779, when he publiſhed it. He compoſed two courſes of mathematics; the one for the marine, the other for the artillery. The foundation of theſe two works was the ſame; the applications only being different, according to the two different objects: theſe courſes have everywhere been held in great eſtimation. In his office of examiner he diſcharged the duties with great attention, care, and tenderneſs. A trait of his juſtice and zeal is remarkable in the following inſtance: During an examination which he held at Toulon, he was told that two of the pupils could not be preſent, being confined by the ſmall-pox: he himſelf had never had that diſeaſe, and he was greatly afraid of it; but as he knew that if he did not ſee theſe two young men, it would much impede their improvement, he ventured to their bed ſides to examine them, and was happy to find them ſo deſerving of the hazard into which he put himſelf for their benefit.

Mr Bezout lived in this employment for ſeveral years, beloved of his family and friends, and reſpected by all, enjoying the fruits and the credit of his labours. But the trouble and fatigues of his offices, with ſome perſonal chagrines, had reduced his ſtrength and conſtitution; he was attacked by a malignant fever, of which he died Sept. 27, 1783, in the 54th year of his age, regretted by his family, his friends, the young ſtudents, and by all his acquaintance in general.

The books publiſhed by him were: 1. Courſe of Mathematics for the uſe of the Marine, with a Treatiſe on Navigation, 6 vols in 8vo, Paris, 1764. 2. Courſe of Mathematics for the Corps of Artillery, 4 vols in 8vo, 1770. 3. General Theory of Algebraic Equations, 1779.

His papers printed in the volumes of the Memoirs of the Academy of Sciences are: 1. On curves, whoſe rectification depends on a given quantity, in the volume for 1758. 2. On ſeveral claſſes of equations that admit of an algebraic ſolution, 1762. 3. Firſt volume of a courſe of mathematics, 1764. 4. On certain equations, &c. 1764. 5. General reſolution of all equations, 1765. 6. Second volume of a courſe of mathematics, 1765. 7. Third volume of the ſame, 1766. 8. Fourth volume of the ſame, 1767. 9. Integration of differentials, &c. vol. 3. Sav. Etr. 10. Experiments on cold, 1777.

BIG BONE *Creek,* in Woodford co. Kentucky, falls into the Ohio from the E. in about N. lat. 39. 17. W. long. 85. 54. It is very ſmall in ſize, and has three branches; the N. weſternmoſt interlocks with Bank Lick Creek, which falls into Licking River. It is only noticeable for the large bones, and ſalt licks near it.—*Morſe.*

BIG BONE LICKS, THE, lie on each ſide of the above-mentioned creek, a little below the junction of the two eaſtern branches, about 8 miles from the mouth of the creek. Theſe, as alſo the other ſalt ſprings, in the weſtern country, are called *Licks,* becauſe the earth about them is furrowed up in a moſt curious manner, by the buffaloes and deer which lick the earth, on account of the ſaline particles with which it is impregnated. A ſtream of brackiſh water runs through theſe licks, the ſoil of which is a ſoft clay.—The large bones found here, and in ſeveral other places near ſalt licks, and in low ſoft grounds, thought to belong to the mammoth, ſtill puzzle the moſt learned naturaliſts to determine to what animal they have belonged. A thigh bone found here by General Parſons, meaſured *forty-nine* inches in length. A tooth of this animal is depoſited in Yale College. Mr Jefferſon,

who

ment was always confined to a few ſatirical verſes, which were generally burnt ſoon after.

"I have frequently admired with what readineſs and rapidity he could ſometimes make verſes. I have known him dictate from thirty to forty verſes, and by no means bad ones, as faſt as I could write them; but the moment he was at a loſs for a rhime or a verſe to his liking, he ſtopt altogether, and could very ſeldom be induced to finiſh what he had begun with ſo much ardour."

This account ſufficiently marks that eager ſenſibility, chaſtened at the ſame time with uncommon gentleneſs of temper, which characteriſed Dr Blacklock, and which indeed it was impoſſible to be at all in his company without perceiving. In the ſcience of mind, this is that diviſion of it which perhaps one would peculiarly appropriate to poetry, at leaſt to all thoſe lighter ſpecies which rather depend on quickneſs of feeling, and the ready conception of pleaſing images, than on the happy arrangement of parts, or the ſkilful conſtruction of a whole, which are eſſential to the higher departments of the poetical art. The firſt kind of talent is like thoſe warm and light ſoils which produce their annual crops in ſuch abundance; the laſt, like that deeper and firmer mould on which the roots of eternal foreſts are fixed. Of the firſt we have ſeen many happy inſtances in that ſex which is ſuppoſed leſs capable of ſtudy or thought; from the laſt is drawn that maſculine ſublimity of genius which could build an Iliad or a Paradiſe Loſt.

Dr Blacklock could never dictate till he ſtood up; and as his blindneſs made walking about without aſſiſtance inconvenient or dangerous to him, he fell inſenſibly into a vibratory ſort of motion of his body, which increaſed as he warmed with his ſubject, and was pleaſed with the conceptions of his mind. This motion at laſt became habitual to him; and though he could ſometimes reſtrain it when on ceremony, or on any public appearance, ſuch as preaching, he felt a certain uneaſineſs from the effort, and always returned to it when he could without impropriety. This appearance he deſcribes in a ſhort poem, in which he gives a ludicrous picture of himſelf; a picture indeed, of which, though the outlines are true, the general effect is greatly overcharged. Though his features were hurt by the diſeaſe which deprived him of ſight, there was a certain placid expreſſion in his countenance, which marked the benevolence of his heart, and was calculated to procure to him individual attachments and general regard.

In 1762 he married Miſs Sarah Johnſon, daughter of Mr Joſeph Johnſon ſurgeon in Dumfries; a connection which formed the great ſolace and bleſſing of his future life, and gave him, with all the tenderneſs of a wife, all the zealous care of a guardian and a friend. This event took place a few days before his being ordained miniſter of the town and pariſh of Kircudbright, in conſequence of a preſentation from the crown, obtained for him by the earl of Selkirk, a benevolent nobleman, whom Mr Blacklock's ſituation and genius had intereſted in his behalf. But the inhabitants of the pariſh, whether from that violent averſion to patronage, which was then ſo univerſal in the ſouthern parts of Scotland, from ſome political diſputes which at that time ſubſiſted between them and his noble patron, or from thoſe prejudices which ſome of them might naturally enough entertain againſt a paſtor deprived of ſight, or perhaps from all theſe cauſes united, were ſo extremely diſinclined to receive him as their miniſter, that after a legal diſpute of nearly two years, it was thought expedient by his friends, as it had always been wiſhed by himſelf, to compromiſe the matter, by reſigning his right to the living, and accepting a moderate annuity in its ſtead. With this ſlender proviſion he removed in 1764 to Edinburgh; and to make up by his induſtry a more comfortable and decent ſubſiſtence, he adopted the plan of receiving a certain number of young gentlemen as boarders into his houſe, whoſe ſtudies in languages and philoſophy he might, if neceſſary, aſſiſt. In this ſituation he continued till the year 1787, when he found his time of life and ſtate of health required a degree of quiet and repoſe which induced him to diſcontinue the receiving of boarders. In 1767 the degree of doctor in divinity was conferred on him by the univerſity and Mariſchal college of Aberdeen.

In the occupation which he thus exerciſed for ſo many years of his life, no teacher was perhaps ever more agreeable to his pupils, nor maſter of a family to its inmates, than Dr Blacklock. The gentleneſs of his manners, the benignity of his diſpoſition, and that warm intereſt in the happineſs of others which led him ſo conſtantly to promote it, were qualities that could not fail to procure him the love and regard of the young people committed to his charge; while the ſociety, which eſteem and reſpect for his character and his genius often aſſembled at his houſe, afforded them an advantage rarely to be found in eſtabliſhments of a ſimilar kind.

In this mixed ſociety he appeared to forget the privation of ſight, and the melancholy which it might at other times produce in his mind. He entered, with the cheerful playfulneſs of a young man, into all the ſprightly narrative, the ſportful fancy, and the humorous jeſt that roſe around him. Next to converſation, muſic was perhaps the ſource of his greateſt delight; for he not only reliſhed it highly, but was himſelf a tolerable performer on ſeveral inſtruments, particularly the flute. He generally carried in his pocket a ſmall *flageolet*, on which he played his favourite tunes; and was not diſpleaſed when aſked in company to play or to ſing them; a natural feeling for a blind man, who thus adds a ſcene to the drama of his ſociety.

Of the happineſs of others, however, we are incompetent judges. Companionſhip and ſympathy bring forth thoſe gay colours of mirth and cheerfulneſs which they put on for a while, to cover perhaps that ſadneſs which we have no opportunity of witneſſing. Of a blind man's condition we are particularly liable to form a miſtaken eſtimate; we give him credit for all thoſe gleams of delight which ſociety affords him, without placing to their full account thoſe dreary moments of darkſome ſolitude to which the ſuſpenſion of that ſociety condemns him. Dr Blacklock had from nature a conſtitution delicate and nervous, and his mind, as is almoſt always the caſe, was in a great degree ſubject to the indiſpoſition of his body. He frequently complained of a lowneſs and depreſſion of ſpirits, which neither the attentions of his friends, nor the unceaſing care of a moſt affectionate wife, were able entirely to remove. The imagination we are ſo apt to envy and admire ſerves but to irritate this diſorder of the mind; and that fancy in whoſe creation we ſo much delight, can draw, from ſources unknown to common men, ſubjects of diſguſt, diſquietude, and affliction. Some of his later poems expreſs a chagrin, though not of an ungentle ſort, at the ſuppoſed failure of his imaginative powers, or at the faſtidiouſneſs of modern times, which he deſpaired to pleaſe.

“ Such were his efforts, ſuch his cold reward,
“ Whom once thy partial tongue pronounc'd a bard;
“ Excurſive, on the gentle gales of ſpring,
“ He rov'd, whilſt favour imp'd his timid wing;
“ Exhauſted genius now no more inſpires,
“ But mourns abortive hopes, and faded fires;
“ The ſhort-liv'd wreath, which once his temples grac'd,
“ Fades at the ſickly breath of ſqueamiſh taſte;
“ Whilſt darker days his fainting flames immure
“ In cheerleſs gloom and winter premature.”

Theſe lines are, however, no proof of “ exhauſted genius,” or “ faded fires.” “ Abortive hopes,” indeed, muſt be the lot of all who, like Dr Blacklock, reach the period of old age. In early youth the heart of every one is a poet; it creates a ſcene of imagined happineſs and deluſive hopes; it clothes the world in the bright colours of its own fancy; it refines what is coarſe, it exalts what is mean; it ſees nothing but diſintereſtedneſs in friendſhip, it promiſes eternal fidelity in love. Even on the diſtreſſes of its ſituation it can throw a certain romantic ſhade of melancholy that leaves a man ſad, but does not make him unhappy. But at a more advanced age, “ the fairy viſions fade,” and he ſuffers moſt deeply who has indulged them the moſt.

About the time that theſe verſes were written, Dr Blacklock was, for the firſt time, afflicted with what to him muſt have been peculiarly diſtreſsful. He became occaſionally ſubject to deafneſs, which, though he ſeldom felt it in any great degree, was ſufficient, in his ſituation, to whom the ſenſe of hearing was almoſt the only channel of communication with the external world, to cauſe very lively uneaſineſs. Amidſt theſe indiſpoſitions of body, however, and diſquietudes of mind, the gentleneſs of his temper never forſook him, and he felt all that reſignation and confidence in the Supreme Being which his earlieſt and his lateſt life equally acknowledged. In ſummer 1791 he was ſeized with a feveriſh diſorder, which at firſt ſeemed of a ſlight, and never roſe to a very violent kind; but a frame ſo little robuſt as his was not able to reſiſt it, and after about a week's illneſs it carried him off on the 7th day of July 1791. His wife ſurvives him, to feel, amidſt the heavy affliction of his loſs, that melancholy conſolation which is derived from the remembrance of his virtues.

The writings of Dr Blacklock conſiſted principally of poems, which were publiſhed in 4to in the year 1793; and to that edition was added, *An Eſſay on the Education of the Blind, tranſlated from the French of M. Hauy.* But beſides his avowed works, we have reaſon to believe that he was the author of many articles in the ſecond edition of the *Encyclopædia*, though we cannot ſay with certainty what thoſe articles were. If our memory does not deceive us, we have been informed that the preface to that edition was furniſhed by him; and we have elſewhere attributed to him, on the beſt authority, the article Blind, and the *Notes* to the article Music: but he undoubtedly contributed much more to the work, and was one of the principal guides of the proprietors.

BLACK *River*. There are two ſmall rivers of this name in Vermont, one falls into Connecticut River at Springfield, the other runs N. into Lake Memphremagog.—*Morſe.*

Black *River*, in N. York, interlocks with Canada Creek, and runs N. W. into Iroquois River, boatable 60 miles. Alſo, a long river which riſes in Virginia, and paſſes ſouth eaſterly into Nottaway River in N. Carolina.—*ib.*

Black *River*, a Britiſh ſettlement at the mouth of Tinto River, 20 leagues to the E. of Cape Honduras, the only harbor on the coaſt of Terra Firma, from the iſland of Rattan to Cape Gracias a Dios, and was for more than 60 years the refuge of the logwood cutters, when the Spaniards drove them from the foreſts of Eaſt Yucatan, which occaſioned adventurers of different kinds to ſettle here, where the coaſt is ſandy, low and ſwampy; higher up near the rivers and lagoons, which are full of fiſh, the ſoil is more fertile, and produces plantanes, cocoa-trees, maize, yams, potatoes, and variety of vegetables; and the paſſion for drinking ſpirits, made them plant ſugar canes. The foreſts are full of deer, Mexican, ſwine and game. The ſhores abound with turtle, and the woods with mahogany, zebra-wood, ſarſaparilla, &c. and indeed the whole ſettlement flouriſhes ſpontaneouſly without cultivation. —*ib.*

Black *River*, in the iſland of Jamaica, paſſes through a level country, is the deepeſt and largeſt in the iſland, and will admit flat bottomed boats and canoes for about 30 miles.—*ib.*

BLADEN, a county of N. Carolina, in Wilmington diſtrict. It has 5084 inhabitants, including 1676 ſlaves.—*ib.*

BLADENSBURG, a poſt town in Prince George co. Maryland, on the eaſtern bank of the eaſtern branch of Potowmack River at the confluence of the N. W. and N. E. branches; 9 miles from its mouth at the Federal City; 38 S. W. from Baltimore, and 12 N. E. from Alexandria, in Virginia. It contains about 150 houſes, and a ware-houſe for the inſpection of tobacco.—*ib.*

BLANCO *Capes.* There are many capes of this name, as follow. 1. The N. weſtern point of the bay of Salinas, in the 10th degree of N. latitude; and on the coaſt of Terra Firma; and, in other maps, is called the N. weſtern point of the gulf of Nicoya.—2. On the coaſt of California, at the broadeſt part of the peninſula, in the 32d degree of N. latitude.—3. On the N. W. coaſt of America, in New-Albion, ſouthward of the mouth of what has been called the *River of the Weſt*, in the 44th degree of N. latitude.—4. A promontory of Peru, in S. America, on the coaſt of the S. Sea, 120 miles S. W. of Guayaquil, S. lat. 3. 45. W. long. 83.—5. A cape in the ſouthern ocean, on the E. ſide of Patagonia, S. eaſtward of Julian Bay, in the 47th degree of S. latitude, 8 leagues W. of Pepys's Iſland.—*ib.*

Blanco, or *Blanca*, an iſland 35 leagues from Terra Firma, and N. of Margarita Iſland in the province of New-Andaluſia. It is flat, low, and uninhabited; having ſavannahs of long graſs; is dry and healthy; has plenty of guanas, and ſome trees of lignumvitæ. N. lat. 11. 50. W. long. 64. 50.—*ib.*

diſengage itſelf, drives out the atmoſpherical air which is in the apparatus: when it is judged that the atmoſpheric air has paſſed into the cavities, it is to be drawn off by means of a bent tube, which is to be introduced ſucceſſively under each cavity: to drive out the water which has entered into the tube, this laſt is to be forcibly blown into. The operation is then ſuffered to go on without fire until it is perceived that the bubbles come over but ſlowly: then a little fire is to be applied, which is not to be haſtily increaſed at the beginning, but may be gradually augmented, ſo that at the end of the operation the matter may be brought to a boiling ſtate. It is known to be nearly finiſhed when the tube by which the gas is diſengaged, and the intermediate veſſel, become hot. When the gas is diſengaged only in a ſmall quantity, the fire may be withdrawn; and when the diſtilling veſſel retains but a gentle warmth, it is to be unluted, and warm water is to be poured upon the reſidue, that it may remain in ſolution, and thereby be more eaſily poured out.

"The operation is longer or ſhorter according to the quantity of materials: with that above mentioned, it ſhould laſt five or ſix hours; it is proper not to haſten it, that a larger quantity of gas may be drawn off. A ſingle perſon is able to manage ſeveral diſtillations at the ſame time; to each of which may be given much larger quantities of materials than thoſe which have been pointed out.

"The intermediate veſſel by degrees becomes filled with a liquor which is pure, though weak, muriatic acid; nevertheleſs, we may perform the operation ſeveral times without extracting it: but when it is ſuppoſed that there is not ſufficient empty ſpace, this acid is to be drawn off by means of a ſyphon, and, when we have collected a ſufficient quantity of it, it may be ſubſtituted for the mixture of vitriolic acid and common ſalt in the operation we have deſcribed, if we have no other uſe to make of it. That there may paſs but a ſmall quantity of muriatic acid, not oxygenated, the firſt tube ought to form a right angle, or even an obtuſe one, with the body matraſs.

"During the operation, the agitator muſt be from time to time put in motion, to favour the abſorption of the gas by the water: when it is finiſhed, the liquor is of a proper ſtrength to uſe in bleaching; or we may put a leſs quantity of water in the tub, and then dilute the liquor according to the proportion already mentioned.

"In this ſtate of concentration, although the liquor has a pretty ſtrong odour, it nevertheleſs is not hurtful, nor even very unpleaſant, to thoſe who uſe it; it is, however, proper to conduct it into the troughs where the cloths are placed by means of wooden canals, which are to be connected with the fauſet or tube which is at the lower part of the tub."—The following is a deſcription of the apparatus:

Plate VII. fig. 1.

ABCD is a reverberatory furnace, having, on a line with B, many ſmall openings in its circumference, to ſerve as chimneys; within which, upon a ſand-bath *a*, is placed a matraſs *b*, the neck of which ſtands out above the furnace, running through the opening D, which is to be cloſed with clay. The mouth F, of the neck of the matraſs, is cloſed by a cork G, through the middle of which paſſes a tube H, which forms a communication between the inſide of the matraſs *b*, and the intermediate veſſel K, where it alſo paſſes through a cork I, which cloſes one of the three openings of that veſſel. The corks G and I ought to be prepared before-hand, and well fitted to each end of the tube of communication H, which is to be ſo diſpoſed that it may be fitted in immediately after the mixture is made in the matraſs.

The intermediate veſſel K is about an eighth part full of water; into it is plunged the tube of ſafety L, to prevent danger from regurgitation. This tube ought to be ſo high, that the weight of the water which enters into it, by the preſſure of the gas, may be great enough to cauſe the gas to paſs into the pneumatic tub NOP, by the tube of communication M, which is plunged therein, and reaches to the bottom, where it is bent horizontally, ſo that the gas may be emitted under the firſt of the three wooden, or (if they can be procured) ſtone-ware, cavities, or receivers, which are placed in the inſide of the tub, one above the other. O is a handle which ſerves to turn the agitator E, the movement of which facilitates the combination of the gas with the water. P is a ſpigot and fauſet to draw off the liquor.

4 Method of bleaching.

It is neceſſary to prepare the cloth by leaving it to ſoak for 24 hours in water, or, which is better, in ſome old ley. Afterwards it ſhould be ſubmitted to the action of one or two good leys; becauſe all the colouring part which may be extracted by the leys would elſe, without any advantage, conſume a part of that liquor which it is important to be as ſparing of as poſſible. After this, the cloth is to be carefully waſhed; then it is to be placed in the troughs, without any part being preſſed or confined, in ſuch a manner that it may be thoroughly impregnated with the liquor which is to run thereon. The troughs, as well as the tub, ought to be conſtructed without iron; for that metal, being ruſted by the oxygenated muriatic acid, would produce iron moulds, which could not be taken out but by means of ſalt of ſorrel.

The firſt immerſion ought to be longer than the others; it may be continued for three hours, after which the cloth is to be taken out; it is to be again ſubmitted to the action of ley, and then placed in a trough, that freſh liquor may be poured thereon: it is ſufficient that this immerſion, and the following ones, continue half an hour. When the cloth is taken from the trough, the liquor is to be wrung out, it is to be again ſubmitted to the ley, and afterwards to freſh immerſions. The ſame liquor may ſerve until its ſtrength is exhauſted: when it is much weakened, there may be ſome freſh liquor added to it. When the cloth appears white, except ſome black threads and the liſts, it is to be impregnated with black ſoap, and then ſtrongly rubbed; after which it is to be ſubmitted to the laſt ley and the laſt immerſion. We cannot determine what number of leys and immerſions may be neceſſary, becauſe it varies according to the nature of the cloth: nevertheleſs, the limits of this number are between four and eight for linen or hempen cloths.

The manufacturers at Javelle, to whom M. Berthollet had communicated this proceſs, ſoon after publiſhed, in different journals, that they had diſcovered a particular liquor which had the property of bleaching cloth by an immerſion of ſome hours only. The change they had made in the proceſs performed in their preſence, conſiſted in putting ſome alkali into the water which receives the gas; this enables the liquor to become much more concentrated, ſo that it may be diluted with ſeveral times its own quantity of water before it is uſed.

“ Theſe are the proportions which yielded me (ſays Berthollet) a liquor ſimilar to the pretended Javelle ley; two ounces and a half of common ſalt, two ounces of ſulphuric acid, ſix drachms of calx of manganeſe, and, in the veſſel where the gas is to be concentrated, one pound of water, and five ounces of potaſh, which ſhould be diſſolved in the water. The Javelle liquor has a ſomewhat reddiſh appearance, occaſioned by a ſmall quantity of manganeſe, which either paſſes in the diſtillation, becauſe an intermediate veſſel is not uſed, or exiſts in the potaſs; moſt kinds of which contain it, as I have well convinced myſelf.”

“ This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more ſpeedily than the liquor itſelf: but without ſpeaking of the imperfections of the method which is deſcribed in the publications from Javelle, and which can only ſuffice for cotton, we are not able to bleach near the ſame quantity of cloth with the oxygenated muriatic acid combined in this manner with an alkali, as might be bleached with the ſame quantity of that acid mixed with water alone; becauſe there is formed a portion of that neutral ſalt which is known at preſent by the name of oxygenated muriate of potaſs, and in which the oxygen becomes concentrated. Now all the oxygen which enters into the compoſition of this ſalt is rendered uſeleſs for bleaching; becauſe the oxygenated muriate of potaſh does not deſtroy colours.”

This method of bleaching was very ſoon adopted in Britain, and is now almoſt univerſal among bleachers. A great many changes have been made in the proceſs; one of the moſt important of which is ſubſtituting lead veſſels for wooden ones, which, beſides weakening its action exceedingly, were very ſoon deſtroyed by the acid. We believe, too, that the bleachers very generally add ſome alkali to the acid, notwithſtanding the ſtrong objections which Mr Berthollet has made to that manner of bleaching.

This method of bleaching has been found to anſwer remarkably well: the only objection that has been made to it is, that the cloth is apt to be weakened. And this, no doubt, muſt be the caſe, if care be not taken to prevent the acid from being too much concentrated; but we have little doubt that, with a ſufficient degree of caution, it will prove as ſafe as any other whatever; and, in point of expedition, there cannot ſurely be any compariſon drawn between the old mode of bleaching and the new.

5
Theory of bleaching.

It remains for us now to conſider, whether the new diſcoveries in chemiſtry do not throw ſome rays of light upon the theory of bleaching; for it is only by perfecting the theory that we can advance with certainty in our practical improvements.

It has been already obſerved, in the article BLEACHING (*Encycl.*), that cloth, after being bleached, was a good deal lighter than it had been before the operation: It follows, therefore, that it muſt have been deprived of ſomething during the bleaching. Cloth bleached by means of the oxy-muriatic acid likewiſe undergoes a loſs of weight; ſo that, in all probability, both modes act in preciſely the ſame manner.

If raw linen or thread be boiled in a ſolution of cauſtic alkali, properly diluted, it gives out ſomething which tinges the ley of a deep brown, and at the ſame time the alkali loſes its cauſticity. If the linen be boiled in another ſimilar ſolution, it communicates the ſame colour, and even a third may be ſlightly tinged; but after this, alkalis, unleſs ſo much concentrated as to injure the texture of the cloth, have no effect on it whatever. If the linen be now plunged into oxy-muriatic acid, properly prepared, and allowed to remain till it begins to become white, and then plunged into an alkaline ley, the alkali loſes its cauſticity, and aſſumes the ſame deep colour that the firſt ley did. Here, then, we have two alkaline ſolutions; the one ſaturated with colouring matter before the action of the oxy-muriatic acid on the linen, the other after it. When theſe ſolutions are ſaturated with an acid, a yellow coloured precipitate is obtained, which when dried aſſumes the appearance of a black powder. Preciſely the ſame ſubſtance is obtained from both ſolutions. This colouring matter is almoſt inſoluble in water. Pure or cauſtic potaſs diſſolves about double its own weight of it; carbonate of potaſs not ſo much.

Hence we ſee the uſe of alkalis in bleaching. The colouring matter is not ſoluble in water, but part of it is ſoluble in alkali. However, after the alkali has exhauſted all its power, the linen is not white: colouring matter, therefore, exiſts in it, which alkalis cannot act upon. But after being plunged in oxy-muriatic acid, it alſo becomes ſoluble in acids. Here, then, is the uſe of that acid in bleaching—it communicates ſomething to the colouring matter which renders it ſoluble in alkali. This ſomething, we have already ſeen, is oxygen. It follows, therefore, that before the greater part of the colouring matter of linen can be extracted by alkalis, it muſt be combined with oxygen. It is in producing this combination that the uſe of the expoſure to the ſun and air conſiſts; and it is becauſe the oxy-muriatic acid produces it almoſt inſtantaneouſly, that the new mode of bleaching is ſo much more expeditious than the old.

If into the alkaline ſolution of the colouring matter lime-water be poured, there takes place a copious precipitate, which conſiſts of the lime and colouring matter combined. Lime, therefore, has a ſtronger affinity for the colouring matter than alkali has: and as the compound of lime and the colouring matter is not very ſoluble in water, lime-water might be uſed to deprive the alkaline ley of the colouring matter which it has imbibed; after which it might be uſed again. Care, however, muſt be taken that no lime-water remains in the ley; otherwiſe it might precipitate and fix the colouring matter in the linen, after which it would be very difficult to remove it.

6
Nature of the colouring matter of linen.

From an alkaline ley, ſaturated with the colouring matter of linen yarn, Mr Kirwan, by means of muriatic acid, precipitated the colouring matter. He found it to poſſeſs the following properties: When ſuffered to dry for ſome time on a filter, it aſſumed a dark green colour, and felt ſomewhat clammy like moiſt clay. “ I took (ſays he) a ſmall portion of it, and added it to 60 times its weight of boiling water, but not a particle of

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it was diſſolved. The remainder I dried in a ſand heat: it then aſſumed a ſhining black colour, became more brittle but internally remained of a greeniſh yellow, and weighed one ounce and an half.

" By treating eight quarts more of the ſaturated ley in the ſame manner, I obtained a further quantity of the greeniſh depoſit; on which I made the following experiments:

" 1ſt, Having digeſted a portion of it in rectified ſpirit of wine, it communicated to it a reddiſh hue, and was in a great meaſure diſſolved: but by the affuſion of diſtilled water the ſolution became milky, and a white depoſit was gradually formed; the black matter diſſolved in the ſame manner.

" 2dly, Neither the green nor the black matter was ſoluble in oil of turpentine or linſeed oil by a long continued digeſtion.

" 3dly, The black matter being placed on a red-hot iron, burned with a yellow flame and a black ſmoke, leaving a coaly reſiduum.

" 4thly, The green matter being put into the vitriolic, marine, and nitrous acids, communicated a browniſh tinge to the two former, and a greeniſh to the latter, but did not ſeem in the leaſt diminiſhed.

" Hence it appears, that the matter extracted by alkalis from linen yarn is a peculiar ſort of reſin, different from pure reſins only by its inſolubility in eſſential oils, and in this reſpect reſembling lacs. I now proceed to examine the power of the different alkalis on this ſubſtance. Eight grains of it being digeſted in a ſolution of cryſtallized mineral alkali, ſaturated in the temperature of 60°, inſtantly communicated to the ſolution a dark brown colour; two meaſures (each of which would contain 11 pennyweights of water) did not entirely diſſolve this ſubſtance. Two meaſures of the mild vegetable alkali diſſolved the whole.

" One meaſure of cauſtic mineral alkali, whoſe ſpecific gravity was 1,053, diſſolved nearly the whole, leaving only a white reſiduum.

" One meaſure of cauſtic vegetable alkali, whoſe ſpecific gravity was 1,039, diſſolved the whole.

" One meaſure of liver of ſulphur, whoſe ſpecific gravity was 1,170, diſſolved the whole.

" One meaſure of cauſtic volatile alkali diſſolved alſo a portion of this matter."

The colouring matter of cotton is much more ſoluble in alkali than that of linen; hence the greater facility with which cotton is bleached.

From theſe obſervations, the great importance of alkalis in bleaching, and the neceſſity of regulating the ſtrength, and aſcertaining the purity, of the leys made uſe of, muſt be apparent. Manufacturers, therefore, lie under very great obligations to Mr Kirwan, who has lately examined the alkaline matters uſed in bleaching with his uſual accuracy and abilities. The reſult of his experiments was as follows:

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Table of the quantity of mere alkali in 100 *Avoirdupois pounds of the following ſubſtances.*

One hundred lbs.	*Mineral Alkali.*
Cryſtallized ſoda - - -	20 lbs.
Sweet barilla - - -	24
Mealy's cunnamara kelp - -	3,437
Ditto deſulphurated by fixed air -	4,457
Strangford kelp - - -	1,25
One hundred lbs.	*Vegetable Alkali.*
Dantzic pearl aſh - - -	63,33 lbs.
Clarke's refined aſh - - -	26,875
Caſhup - - - -	19,376
Common raw Iriſh weed-aſh - -	1,666
Ditto ſlightly calcined - -	4,666

When linen is allowed to remain for ſome time in oxy-muriatic acid, it becomes white. It is evident, then, that when the colouring matter of linen is ſaturated with oxygen, it becomes colourleſs: But linen bleached in this manner very ſoon becomes yellow, eſpecially when expoſed to heat. Berthollet, to whoſe ingenious experiments and obſervations we are indebted for the greater part of the above remarks, has given the following explanation of the cauſe of this change: He diſtilled the colouring matter of linen, and obtained a thick oil, a little ammonia, and $\frac{24}{100}$ of carbon remained behind. The oil contained carbon; and he ſuppoſed that carbonic acid gas, and carbonated hydrogen gas, were diſengaged. He concluded in conſequence, that one-third of this colouring matter was carbon. The other ingredient in the oil was hydrogen; for Lavoiſier has proved that oil is compoſed of oxygen and hydrogen. The colouring matter of linen, then, is compoſed principally of carbon and hydrogen.

Oxygen combines with hydrogen at a lower temperature than it does with carbon; for if a conſiderable quantity of oxy-muriatic acid be mixed with a ſolution of ſugar (a ſubſtance which conſiſts chiefly of carbon and hydrogen), and the liquor be evaporated, there remains behind little elſe than carbon, the hydrogen having combined with oxygen and formed water, which had paſſed off in the form of vapour. Now, whenever a quantity of hydrogen is ſeparated from a body principally compoſed of hydrogen and carbon, that body aſſumes a brown or yellow colour, becauſe the carbon becomes predominant; and this colour becomes the deeper the greater the proportion of the carbon is, compared to that of the hydrogen; and at laſt, when nothing but carbon remains, it becomes quite black.

It is probable, then, that when the oxy-muriatic acid renders linen white, a quantity of oxygen has combined with the colouring particles, but that this oxygen gradually enters into a combination with the hydrogen, and forms water which paſſes off; that then the carbon becomes predominant, and the linen in conſequence aſſumes a yellow colour.*

7
Bleaching of wool an ſilk.

The ſame method does not ſucceed in bleaching wool and ſilk which anſwers for linen and cotton. One would be diſpoſed to think that theſe ſubſtances are bleached rather by loſing oxygen than by abſorbing it. Wool, for inſtance, is rendered white very quickly when expoſed to the fumes of ſulphurous acid, which we know has a ſtrong affinity for oxygen, and ſoon ſaturates itſelf with it. But what paſſes during the whitening of animal matters has never yet been properly enquired into, though it would not only greatly elucidate *bleaching*, but *dying* likewiſe, and throw much light upon ſome of the obſcureſt parts of chemiſtry. A great improvement, however, has lately been made by M. Baumé in the manner of bleaching ſilk. Of this improvement we ſhall proceed to give an account.†

Before the ſilk is wound off the cocons in which the ſilk worms are incloſed, it is neceſſary to kill the inſects,

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* *Ann. de Chym.* VI. 210.

† See the memoir in the *Ann.* *Chym.* xvi 156, and a bridged in *Nicholſon's Journal*, I 32, from which laſt we have ta ken our ac count of i

8
New mode of whitening ſilk.

ſects, otherwiſe they would in all probability eat thro' it and deſtroy it. This is commonly done by expoſing the cocons, properly wrapped up, for two hours to the heat of about 158 degrees of Fahrenheit in an oven; after which they are kept for a certain time in a maſs to preſerve their heat, and effectually deſtroy ſuch of the inſects as might have eſcaped the power of the oven. The effect of this proceſs is, that the ſilk is hardened, and is more difficult to wind off than before. Hence the product of ſilk is leſs by one-ninth part in quantity, and inferior in quality to what might have been obtained by winding off without this previous baking. Mr Baumé, not only from theſe views, but likewiſe becauſe the ſilk which has not been baked proves ſuſceptible of a greater luſtre, was induced to deſtroy the cryſalis by ſpirit of wine. For this purpoſe he diſpoſes them in a wooden box in a ſtratum ſix inches deep: upon each ſquare foot half a pint of ſpirit of wine is to be ſprinkled with a ſmall watering pot made for that purpoſe. The liquid is to be equally diſtributed, but it is not neceſſary that all the cocons ſhould be wetted. They are then to be mixed by hand. In the next place another ſtratum is to be formed over the firſt, nearly of the ſame depth, which is to be ſprinkled and treated as before. By this method of proceeding, the box becomes filled, and muſt then be covered, and left for 24 hours, during which time they become ſpontaneouſly heated to about 100 degrees, and the vapour of the ſpirit of wine exerts itſelf with wonderful activity. After this treatment they muſt be ſpread out to dry, which happens in a ſhort time, and is abſolutely neceſſary previous to winding off.

The ſpirit of wine to be uſed in this operation ought to be of the ſpecific gravity .847, at the temperature of 55 degrees. It is of the greateſt importance to uſe that ſpirit only which has been kept in veſſels of glaſs, of tinned copper, or of pure tin, Leaden veſſels are abſolutely to be rejected; wooden veſſels tinge the ſpirit, which gives the ſilk a degree of colour of conſiderable permanency, and very inimical to the bleaching proceſs.

The ſilk is wound off upon a reel, while the cocons are kept immerſed in water almoſt boiling. Upon this part of the proceſs M. Baumé remarks, 1ſt, That the dead cocons muſt be ſeparated. Theſe are known by the brown or black ſpots on their ſurface. 2. That well water, which on account of its clearneſs is almoſt univerſally uſed in the ſilk manufactories, moſtly contains nitre, and is extremely prejudicial to the bleaching proceſs. The preſence of nitrous acid gives a yellow colour, which reſiſts bleaching and even ſcouring; he therefore recommends river-water. 3. In ſome countries a ſmall quantity of alum is uſed. Neither this nor any other ſaline ſubſtance is of the leaſt advantage to the colour, beauty, or quality of the ſilk.

At the four places of contact of the ſilk upon the reel, all the threads ſtick together. It is abſolutely neceſſary that this ſhould be remedied. The method conſiſts in ſoaking the ſilk in a ſufficient quantity of warm water, at about 90 degrees, for about two hours; after which the threads are to be ſeparated by opening the hanks upon a pin, and lightly rubbing the parts which cohere. When the ſilk is dry it is to be looſely folded in its original form, and is ready for bleaching.

The ſilk while wet is ſoft, and part of its gummy matter is in ſuch a ſtate, that its threads would readily adhere, if wrung while warm for the purpoſe of clearing it of the water. After ſuch improper treatment there would be no other remedy than to ſoak it again in warm water.

The apparatus for bleaching the ſilk conſiſts of a ſtone-ware veſſel, nearly of a conical form, capable of holding about 12 gallons, having a large opening at the one end, and a ſmaller of about an inch diameter at the other end. Common pottery cannot be uſed in this operation, becauſe it is ſoon rendered unſerviceable by the action of the muriatic acid, and the ſtone-ware itſelf is not very durable. This veſſel muſt be carefully examined, to aſcertain that it does not leak in the ſlighteſt degree; after which the inſide is to be rubbed with a pumice-ſtone, to clear it of aſperities which might break the threads. A cover of the ſame material is to be fitted on by grinding; and the ſmaller aperture, which in the uſe is the loweſt, is to be cloſed with a good cork, in the middle of which is thruſt a ſmall glaſs tube about a quarter of an inch in diameter; this is likewiſe ſtopped with a cork, excepting at the time when it is required to draw off the liquid contents of the jar. A ſmall perforated falſe bottom is placed within the veſſel, to prevent this tube from being obſtructed.

Six pounds of yellow raw ſilk are to be diſpoſed in the earthen pot; upon this is to be poured a mixture, previouſly made, of 48 pounds of ſpirit of wine of the ſpecific gravity .867, with 12 ounces of very pure marine acid, abſolutely exempt from all preſence of nitrous acid, and of the ſpecific gravity 1.114. The pot is then to be covered, and the whole left in digeſtion till the following day, or until the liquor, which at firſt aſſumes a fine green colour, ſhall begin to aſſume that of a duſky brown.

The acidulated ſpirit is then to be drawn off, clean ſpirit of wine poured upon the ſilk, and drawn off repeatedly until it paſſes colourleſs. The ſilk is then ſuffered to drain without ſtirring it. In this ſtate it is ready for a ſecond infuſion.

Forty-eight pounds of ſpirit of wine, acidulated with 12 ounces of marine acid, is now to be poured on the ſilk, and the whole ſuffered to remain for 24 hours or longer, until the ſilk becomes perfectly white. The time required for this ſecond infuſion is commonly longer than for the firſt: it ſometimes amounts to two, three, or even ſix days, according to circumſtances, particularly the temperature and the nature of the ſilk. Silk which has been in the oven is in general more difficult to bleach.

When the ſilk has thus obtained its utmoſt degree of whiteneſs, the acidulated ſpirit is to be drawn off into a ſeparate veſſel. This fluid is but ſlightly coloured, and may be uſed again in the firſt infuſion of other yellow ſilk, with the addition of ſix ounces more of marine acid. The receiving veſſel is to be removed, and another clean veſſel ſubſtituted in its place. The ſilk is then ſprinkled with clean ſpirit, and occaſionally preſſed down with the hand. As ſoon as the ſpirit of wine comes off abſolutely colourleſs, a third infuſion is to be made by pouring upon the ſilk 48 pounds of the pure ſpirit without acid, which is to remain till the following day: it is then to be drawn off, and reſerved for waſhing other ſilk after the firſt infuſion.

After the ſilk has been left to drain, and affords no more ſpirit, it ſtill retains its own weight of that fluid. This

In the ſecond proceſs for diſtilling without alkali, the acid ſpirit is diſtributed into a great number of glaſs retorts, placed in the ſand-bath, on the gallery of a furnace. The firſt product is ſcarcely acid; but what follows is more and more ſo, and muſt be kept in veſſels of glaſs or ſtone-ware, which become embarraſſing on account of their number. The fluid which remains in the retorts has the colour of beer ſlightly turbid, and contains the greateſt part of the marine acid. It muſt be poured into one or more retorts, and concentrated by heat gradually applied. The firſt liquor which comes over is ſlightly red, turbid, and ſcarcely acid. This is to be thrown away, and the receivers changed. The ſucceeding product is the colourleſs marine acid, of an aromatic ſmell reſembling the buds of poplar. The reſin of the ſilk remains in the retort decompoſed by the acid. The marine acid thus obtained is weaker than it originally was; which is in fact of little conſequence, as it is pure, and may be ſafely uſed, either by increaſing the doſe proportional to its diminiſhed ſtrength, or by concentrating it if required in the uſual way. If this diſtillation be made in a ſilver alembic, inſtead of retorts of glaſs, and a capital and worm of pure tin be annexed, the alcohol will be obtained ſo ſlightly acid as ſcarcely to redden the tincture of turnſol; but it is ſufficiently acid to receive injury if preſerved in a copper veſſel.

10
And of preparing a pure muriatic acid.

As to the acid, Mr Baumé obſerves, that the muriatic acid of commerce is unfit for the purpoſe. It was formerly prepared with the marine ſalt of the ſaltpetre manufacturers; and even when it is made with good ſalt, the decompoſition is effected with common vitriolic acid which contains nitrous acid. Marine acid mixed with a ſmall quantity of nitrous acid does not prevent the ſilk from being beautifully whitened: it even accelerates the proceſs conſiderably, and in the moſt ſatisfactory manner. But the alcohol, every time it is uſed and rectified, becomes charged with the acid and gas of nitre, which aſſume the characters of the nitrous anodyne liquor. In this ſtate neither diſtillations nor repeated rectifications from alkali are ſufficient to ſeparate the nitrous matter from the alcohol. Then it is that the ſucceſs of the operator vaniſhes, with a degree of rapidity equal to the advances which encouraged his hopes at the commencement.

To purify common ſulphuric acid, 100 pounds of it are to be mixed in a large baſon of copper with the ſame quantity of river-water, and ſtirred with a wooden ſpatula. The mixture inſtantly becomes heated to the boiling water point, and a great quantity of red vapour is diſengaged, which has the ſmell of aqua-regia, and ariſes from the nitric and muriatic acids. When this mixture is made, it is proper to immerſe the baſon to a ſuitable depth in a large veſſel of water, to haſten the cooling. As ſoon as it is ſufficiently cooled, it is to be drawn off into bottles, and left to become clear during ſeveral days. It is in the next place to be decanted, and conveyed into retorts by a ſyphon funnel, and the rectification proceeded upon until it becomes perfectly white. Towards the end of the operation a ſmall quantity of ſulphur ſublimes in the neck of the retort. Inſtead of receivers, a ſmall glaſs cup is placed beneath the aperture of each retort, in order to facilitate the diſſipation of the nitric and muriatic acids. When the acid in the retorts is ſufficiently cooled, it is poured a ſecond time into the copper baſon, and mixed with 100 pounds of river-water, as at firſt, and again concentrated in the retorts till it becomes perfectly clear. The muriatic acid is to be diſengaged from common ſalt by the application of this acid in the uſual manner.

11
Bleaching paper.

The oxy-muriatic acid is alſo uſed very generally for bleaching paper, or rather the ſtuff out of which paper is made. It has been alleged and we believe with ſome truth, that ſince this mode of whitening paper was introduced into this country, the ſtrength of paper is much inferior to what it was formerly. If this be really the caſe, perhaps it is owing to the uſe of too concentrated an acid.

We ſhall finiſh this article with Mr Chaptal's account of this proceſs, who was the firſt perſon that introduced it. "Blotting paper (ſays he), by being put into oxygenated muriatic acid, is bleached without ſuffering any injury; and rags of coarſe bad cloth, ſuch as are uſed in the paper manufactories to make this kind of paper, may be bleached by this acid, and will then furniſh paper of a very ſuperior quality. I bleached by it an hundred weight of paſte, intended to be made into blotting paper, and the increaſe of value in the product was computed at 25 *per cent.* whereas the expence of the operation, when calculated in the ſtricteſt manner, amounted only to 7 *per cent.*

12
Mode of whitening old books,

"The property poſſeſſed by this acid, of bleaching paper without injuring its texture, renders it very valuable for reſtoring old books and ſmoked prints. The latter, when diſcoloured to ſuch a degree that the ſubject of them could hardly be diſtinguiſhed, were re-eſtabliſhed and revived, in ſo aſtoniſhing a manner that they appeared to be new; and old books, ſoiled by that yellow tinge which time always produces, may be ſo completely renewed, that one might ſuppoſe them to be juſt come out of the preſs. The ſimple immerſion of a print in oxgenated muriatic acid (leaving it therein a longer or a ſhorter time, according to the ſtrength of the liquor (is all that is required for bleaching it; but when a book is to be bleached, ſome farther precautions are to be uſed. As it is neceſſary that the acid ſhould wet every one of the leaves, the book muſt be completely ſpread open, and then, by letting the boards of the binding reſt upon the ſides of the veſſel, the paper only will be immerſed in the liquor. If any of the leaves ſtick together, they muſt be carefully ſeparated, that all of them may be equally impregnated. The liquor takes a yellow tinge, the paper grows white; and after two or three hours the book may be taken out of the liquor, and ſoaked in clean water, which ſhould be changed from time to time, in order to waſh out the acid with which the book is impregnated, and alſo to deprive it of the diſagreeable ſmell it has contracted.

"The above method, which is the firſt I made uſe of, has generally ſucceeded pretty well; too often, however, the leaves of my books have had a motely appearance, and ſometimes ſeveral pages were not at all bleached; I was therefore obliged to have recourſe to the following more certain proceſs. I began by unſewing the books, and reducing them into ſheets; theſe ſheets I placed in diviſions made in a leaden veſſel; by means of thin ſlips of wood, ſo that the leaves when laid flat were ſeparated from each other by very ſmall intervals. I then put the acid into the veſſel, pouring it againſt the ſide, that the leaves might not be diſturbed; and when the operation was finiſhed, I drew off the acid, by means of a cock fixed in the bottom of the veſſel. I then filled the veſſel with clean water, which waſhed the leaves, and took off the ſmell of the oxygenated acid. They may then be dried, ſmoothed, and new bound. In this manner I have reſtored many valuable books, which had become worthleſs from the bad ſtate they were in.

13 And prints. "When I had to bleach prints ſo torn to pieces that they conſiſted only of fragments fitted together, and paſted upon paper, I was afraid I might loſe ſome of theſe fragments in the liquor, becauſe they ſeparate from the paper by the ſoftening of the paſte; in that caſe therefore I took the precaution of encloſing the print in a large cylindrical bottle which I turned upſide-down, fixing its mouth to that of a veſſel in which I had put a mixture proper for diſengaging oxygenated muriatic gas. This gas fills the inſide of the bottle, and, acting upon the print takes off the ſtains, ink-ſpots, &c. while the fragments remain paſted to the paper, and conſequently keep their reſpective places."

BLOCK *Iſland*, called by the Indians *Maniſſes*, lies about 21 miles S. S. W. of Newport, and is in Newport co. ſtate of Rhode-Iſland. It was erected into a townſhip, named *New-Shoreham*, in 1672. This iſland is 46 miles in length, and its extreme breadth is 38 miles. It has 682 inhabitants, including 47 ſlaves. It is famous for cattle and ſheep, butter and cheeſe: round the ledges of the iſland conſiderable quantities of cod fiſh are caught. The ſouthern part of it is in N. lat. 41. 8.—*Morſe.*

BLOCKLEY, a townſhip in Philadelphia co. Pennſylvania.—*ib.*

BLOCKS (*Encycl.* Plate XCV. fig. 5) *a*, Repreſents a ſingle block, and *b*, *c*, two double ones of different kinds, without ſtrops; *e*, *f*, two double tackle blocks, iron bound, the lower one, *f*, being fitted with a ſwivel; *g*, a double iron block with a large hook; *h*, a ſmall block; *i*, a top block: *k*, a voyal block; *l*, a clew garnet block; *m*, the cat block, employed to draw the anchor up to the cat-head. See *Cat-Head*, Encycl.

BLUE HILL, a townſhip in Hancock co. Diſtrict of Maine, on the W. ſide of Union River, 344 miles N. E. of Boſton, and 13 E. of Penobſcot; having 274 inhabitants.—*Morſe.*

Blue Hill *Bay*, is formed by Naſkeag Point on the W. and Mount Deſart Iſland on the E. It extends northerly up to a mountain on the E. of Penobſcot River, which, from its appearance at ſea, is called *Blue Hill*. Union River empties into this bay.—*ib.*

Cape or Large Snouted BOAR, a ſpecies of the genus Sus, which, according to M. Vaillant, differs from every known ſpecies, and has not been accurately deſcribed by any writer of natural hiſtory. Buffon, indeed, in the Supplement to his Hiſtory of Quadrupeds, has given a figure of it; but nothing like the head of the animal is diſcoverable, ſays our author, in that figure, all its characteriſtics having been omitted by the draughtſman. M. Vaillant, during his laſt travels in Plate VII. Africa, ſhot a monſtrous boar of this ſpecies on the banks of Fiſh-river, and in the country of the Greater *Nimiquas*. He deſcribes it in the following terms: Its ſnout, inſtead of being taper and in the form of a proboſcis, is, on the contrary, very broad and ſquare at the end. It has ſmall eyes, at a very little diſtance from each other, level with the ſurface, and near the top of the forehead. On each cheek a very thick cartilaginous ſkin projects horizontally, being about three inches long and as many broad. At firſt ſight you would be tempted to take theſe excreſcences for the ears; particularly as the real ears of the animal, ſticking as it were to the neck, which is very ſhort, are partly concealed by an enormous mane, the briſtles of which, in colour red, brown, and greyiſh, are 16 inches in length on the ſhoulders. Directly below theſe falſe ears is a bony protuberance on each ſide, projecting more than an inch, ſerving the animal to ſtrike with to the right and left. The boar has, beſides, four tuſks, of the nature of ivory, two in each jaw: the upper ones are ſeven or eight inches long; very thick at the baſe, and terminating in an obtuſe point, grooved, and riſing perpendicularly as they iſſue from the lips: the lower ones are much ſmaller, and ſo cloſe to the upper ones when the mouth is ſhut, that they appear as one. The head is a truly hideous object. It is ſcarcely leſs ſo than that of the hippopotamus, to which at firſt view it appears to have a ſtriking reſemblance. Syſtematiſts, accuſtomed to view nature only according to rules eſtabliſhed by themſelves, will be far from acknowledging this animal to be a boar; for, not to mention its large ſnout, it wants inciſive teeth in both jaws. Notwithſtanding its wide muzzle, it ploughs up the earth to ſeek for roots, on which it feeds. It is very active, though large and bulky; running with ſuch ſpeed, that the Hottentots give it the name of the *runner*.

BOEUF, LE, a place in the N. weſtern corner of Pennſylvania, at the head of the N. branch of French Creek, and 50 miles from Fort Franklin, where this Creek joins the Alleghany; meaſuring the diſtance by water. The French fort of Le Boeuf, from which the place has its name, lay about 2 miles E. from Small Lake, which is on the N. branch of French Creek; and from Le Boeuf, there is a portage of 14 miles northerly, to Preſque Iſle, in Lake Erie; where the French had another fort.

From Le Boeuf, to Preſque Iſle, is a continued cheſnut-bottom ſwamp (except for about one mile from the former, and two from the latter) and the road between theſe two places, for 9 miles, 15 years ago, was made with logs, laid upon the ſwamp. N. lat. 42. 1. W. long. 79. 53. 20.—*ib.*

BOLTON, a townſhip in Chittenden co. Vermont, on Onion River, about 104 miles N. N. E. from Bennington, having 88 inhabitants.—*ib.*

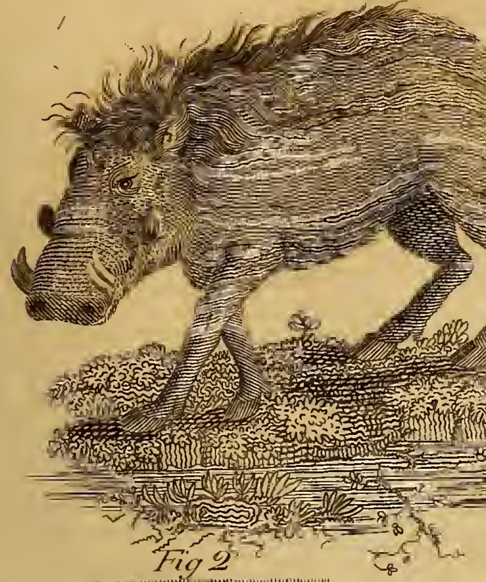
Bolton, a townſhip in Tolland co. Connecticut, incorporated in 1720; and was ſettled from Weathersfield, Hartford, and Windſor, 14 miles E. from Hartford.—*ib.*

Bolton, a townſhip in Worceſter co. Maſſachuſetts; 18 miles N. E. from Worceſter, and 34 W. from Boſton. It contains 861 inhabitants.—There is a fine bed of limeſtone in this town, from which conſiderable quantities of good lime are made yearly.—*ib.*

BOMBAY *Hook*, an iſland at the mouth of Delaware River about 8 miles long and 2 broad, formed by the Delaware on the eaſtern ſide, and Duck Creek and Little Duck Creek on the Maryland ſide; theſe are united together by a natural canal. It is propoſed to connect Delaware River with Cheſapeak Bay, by

PLATE VII.

LARGE SNOUTED BOAR



BLEACHING

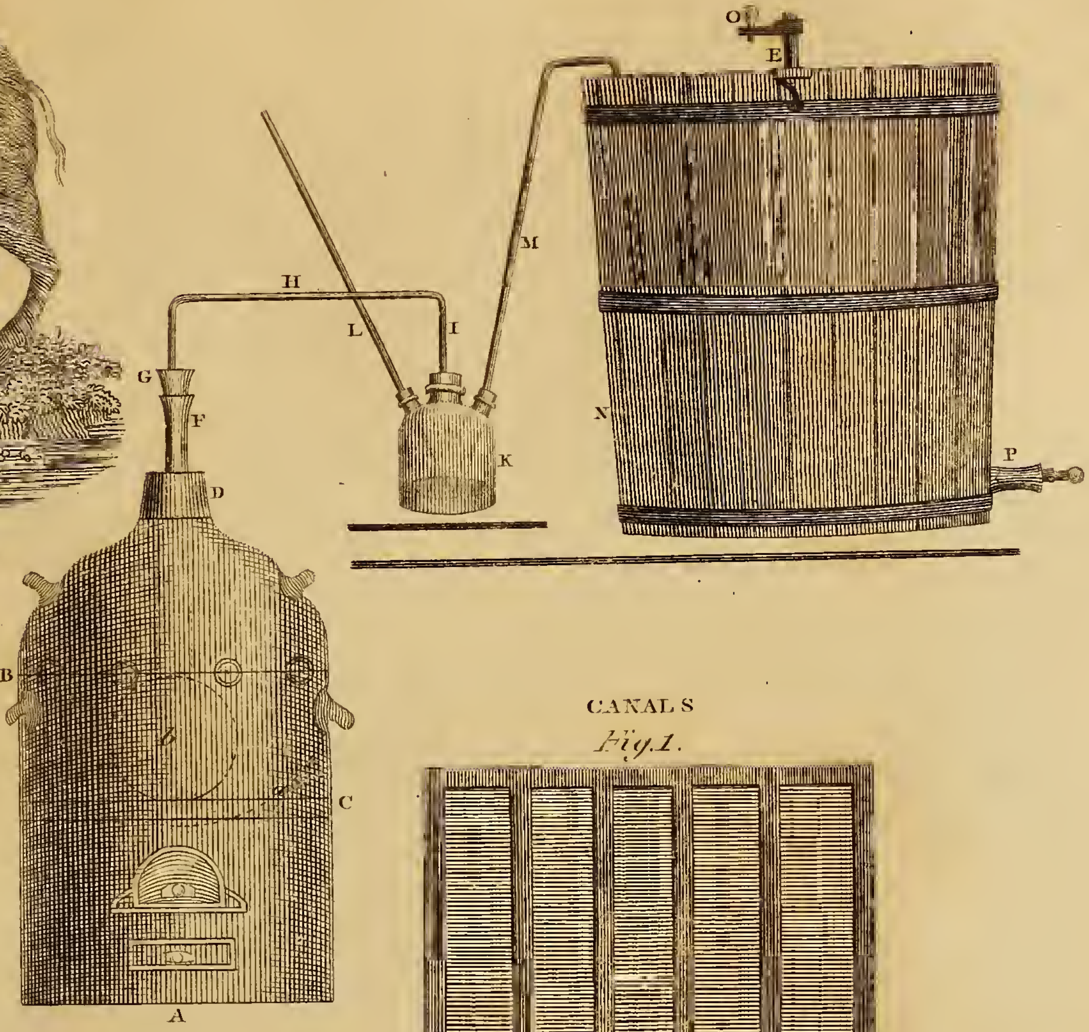
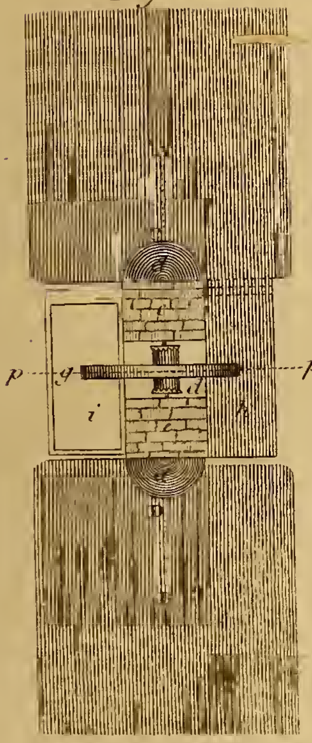


Fig 2



CANALS

Fig. 1.

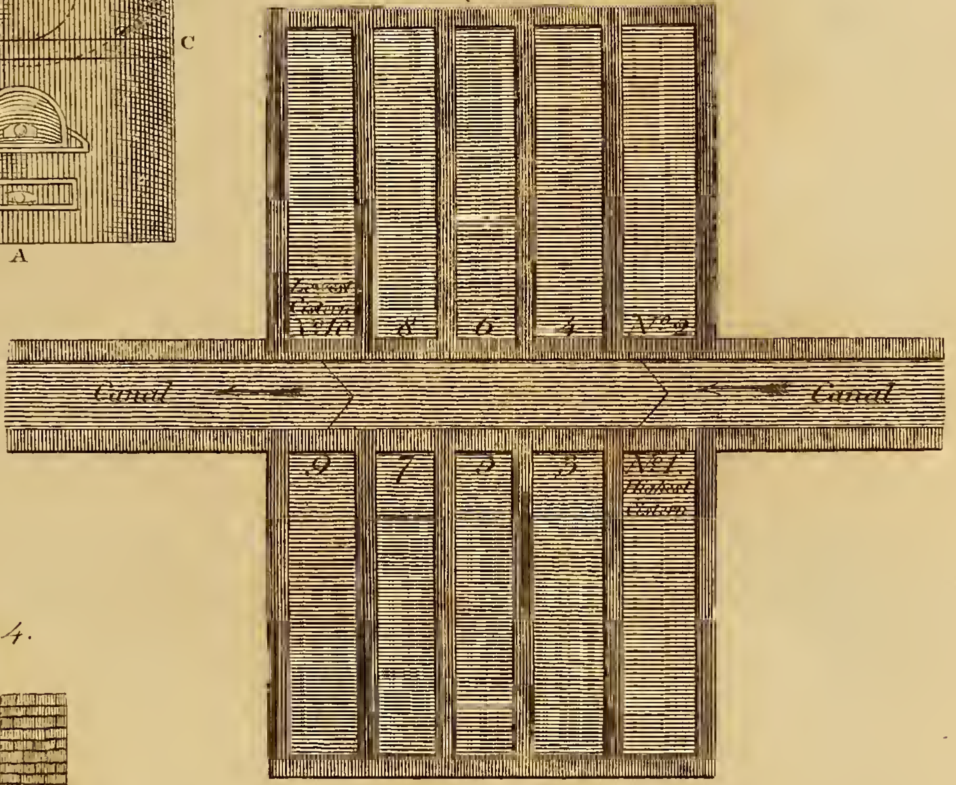


Fig. 3.

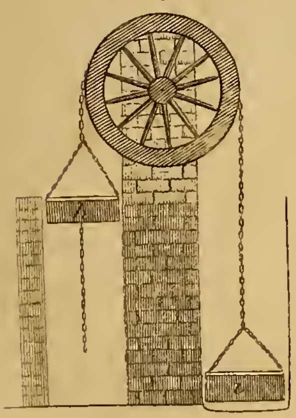


Fig. 4.

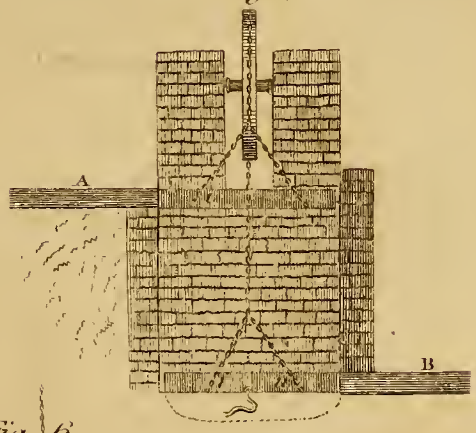


Fig. 5.

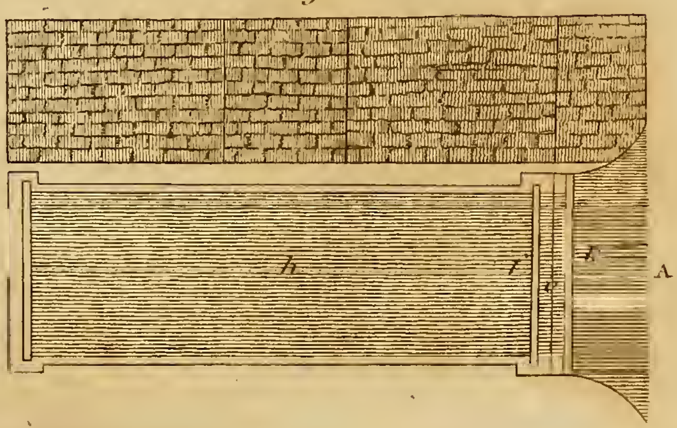
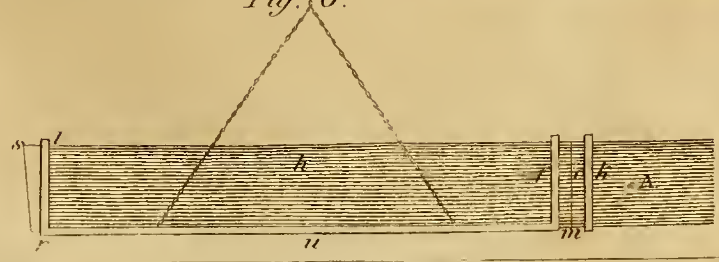


Fig. 6.



Lowry sc.

by a canal from Duck Creek to that bay, through Cheſter River. The N. W. end of Bombay Hook is about 47 miles from Capes Henlopen and May, from the Hook to Reedy Iſland is 9 miles.

BONET (Theophilus), was born at Geneva in the year 1620. His parents were able to give him the moſt liberal education, and his genius directed him to the ſtudy of phyſic; and that he might have every advantage, he attended on the lectures of the moſt eminent profeſſors in many of the celebrated univerſities in Europe. In 1643 he was admitted to the degree of M. D. and was for ſome time phyſician to the Duke of Longueville. His ſuperior ſkill in his profeſſion ſoon brought him into conſiderable repute; but being ſeized with an exceſſive deafneſs, he was obliged to retire from buſineſs when about 60 years of age.

During this retirement he employed himſelf in collecting all the obſervations which he had made in a practice of forty years duration, and in arranging them under proper heads. His firſt publication, which was intitled *Pharos Medicorum*, &c. conſiſts of practical cautions, extracted moſtly from the works of Bellonius; and in it he points out many errors which then prevailed in the general practice of phyſic. Of this work he gave to the world a ſecond edition, conſiderably improved and greatly enlarged; and in 1687 it was a third time printed at Geneva, under the title of *Labyrinthi medici extricati*, &c.

In 1675 he publiſhed *Prodromus anatomiæ practicæ, ſive de abditis morborum cauſis*, &c. This was intended merely as an introduction to a work that ſoon followed, under the title of *Sepulchretum, ſive anatomia practica ex cadaveribus morbo denatis*. In theſe two publications he has collected a great number of curious obſervations upon the diſeaſes of the head, breaſt, belly, and other parts of the body.

In 1682 appeared at Geneva *Mercurius Compitalius, ſive index medico-practicus per deciſiones, cautiones*, &c. in folio; and in 1684 and 1686 two volumes in folio likewiſe, intitled *Medicini Septentrionalis collatitia*. This laſt work is a collection of the beſt and moſt remarkable obſervations in phyſic which had been then made in England, Germany, and Denmark, which Dr Bonet arranged under proper heads, according to the ſeveral parts of the human body. At Geneva, in 1692, was publiſhed, in three volumes folio, *Polyalthes, ſive Theſaurus medica practicus ex quibuſlibet rei medicæ ſcriptoribus congeſtus*, &c. and ſome years before, he gave to the world correct editions of *Theodori Turqueti de Maerne tractatus de arthritide, una cum ejuſdam aliquot conſiliis;* and of *Jacobi Rohaulti tractatus phyſicus e Gallico in Latinum verſus*. This laborious and uſeful author died of a dropſy on the 29th of March 1698.

BONNET (Charles), was deſcended from a French family, who being compelled, on account of their religious principles, to emigrate from their native country, eſtabliſhed themſelves at Geneva in the year 1572. His grandfather was advanced to the magiſtracy in that city, and adorned by his integrity an eminent ſtation. His father, who preferred the ſtation of a private citizen, paid unremitted attention to the education of his ſon, who was born on the 13th of March 1720; and Charles, at a very early period, recompenſed his father's aſſiduity, by the amiableneſs of his diſpoſition, and the rapid progreſs he made in general literature. When he was about 16 years of age, he applied himſelf, with great eagerneſs, to the peruſal of *Le Spectacle de la Nature;* and this work made ſuch a deep impreſſion on his mind, that it may be ſaid to have directed the taſte and the ſtudies of his future life. What that publication had commenced, was confirmed by the work of *La Pluche;* but having accidentally ſeen the treatiſe of *Reaumur* upon inſects, he was in a tranſport of joy. He was very impatient to procure the book; but as the only copy in Geneva belonged to a public library, and as the librarian was reluctant to entruſt it in the hands of a youth, it was with the utmoſt difficulty that he could obtain his end.

By the poſſeſſion of this treaſure, our aſſiduous youth was enabled to make ſeveral new and curious experiments, which he communicated to Reaumur himſelf; and the high applauſe he gained from ſo great a naturaliſt added freſh vigour to his aſſiduity.

In compliance with his father's deſires, he applied himſelf, though with much reluctance, to the ſtudy of the law. The works of *Burlamaqui* pleaſed him the moſt, on account of the perſpicuous and philoſophic manner in which the ſubject was treated: the inſtitutes of *Heineccius* gave him ſome courage alſo, as he perceived order and connection; but the Roman law terrified him as the *hydra of Lerna*. Notwithſtanding his application to theſe authors, he ſtill continued attached to natural hiſtory, and was very active in making experiments. The experiments which demonſtrate that tree-lice propagate without copulation, was communicated by Reaumur to the Academy of Sciences; and this circumſtance occaſioned an epiſtolary correſpondence between M. Bonnet and that great naturaliſt. This was doubtleſs very flattering to a youth of twenty years. The letter of Reaumur was accompanied with a preſent of that very book which he had borrowed with ſo much difficulty two years before.

Animated by ſuch diſtinguiſhed marks of approbation, he diligently employed every moment he could ſteal from the ſtudy of juriſprudence to the completion of his natural hiſtory of the tree-louſe; to experiments on the reſpiration of catterpillars and butterflies, which he diſcovered to be effected by ſtigmata, or lateral pores; to an examination of the conſtruction of the tænia or tap-worm; in frequent correſpondence with Reaumur; and in aſſiſting Trembley in his diſcoveries and publication concerning millepedes, &c. Having in the year 1743 obtained the degree of doctor of laws, he relinquiſhed a purſuit which he had commenced with ſo much reluctance. In the ſame year he was admitted a fellow of the Royal Society, to which he had communicated a treatiſe on inſects.

Bonnet being now liberated from his other purſuits, applied himſelf, without intermiſſion, to collecting together his experiments and obſervations concerning the tree-louſe and the worm, which he publiſhed in 1744 under the title of *Inſectology*. This work acquired deſerved approbation from the public, and was honoured by the commendation of the celebrated B. de Juſſieu. He was reproached, however, in a periodical publication, with having paid too little attention to the delicacy of his reader; though his patience and accuracy were acknowledged to be deſerving of praiſe. Such unremitted application and labour could not fail of becoming injurious to his health. Inflammations, nervous fever, ſore eyes, &c. compelled him to relinquiſh the uſe of the microſcope and the ſtudy of inſects. This prevention was ſo extremely mortifying to a man of his taſte and activity of mind, that he was thrown into a deep melancholy, which could only be ſubdued by the reſolution inſpired by philoſophy, and the conſolations of religion: theſe gradually rouſed him from a dejected ſtate of mind. About the end of the year 1746 our philoſopher was choſen member of the Literary Inſtitution at Bologna, which introduced him to a correſpondence with the famed Zanotti, who may be deemed the Fontenelle of Italy.

In the year 1747 he undertook a very difficult work on the leaves of plants; which, of all his publications in natural hiſtory, bore the ſtrongeſt marks of originality, both with reſpect to the manner in which his experiments were made, and the diſcoveries reſulting from them. His extreme attachment to natural hiſtory gradually led him to a ſtudy of a very different nature; ſpeculative philoſophy now engaged his whole attention. The firſt fruits of his meditations in this department was his *Eſſay on Pſychology*. In this work the principal facts obſervable in human nature, and the conſequences reſulting from them, are ſtated in a conciſe and conſpicuous manner. He contemplated man from the firſt moment of his exiſtence, and purſued the developement of his ſenſes and faculties from ſimple growth up to intelligence. The work, which was publiſhed without his name, met with great oppoſition, and was criticiſed with ſeverity; but the cenſures were directed more againſt his expreſſions than his principles; nor were they of ſufficient importance to impede the general acceptance of the publication.

His analyſis of the mental faculties was ſimply a developement of the ideas contained in the preceding work. It engaged his inceſſant attention for the ſpace of five years; nor was it completed before 1759. It is ſomewhat ſingular that both he and the Abbé de Condillac ſhould have illuſtrated their principles by the ſuppoſition of a ſtatue, organized like the human body, which they conceived to be gradually inſpired with a ſoul, and the progreſſive developement of whoſe powers they carefully traced. In the year 1760 this work was publiſhed at Copenhagen, by order and at the expence of Frederick V. and it was followed in 1762 by contemplations on organized bodies. In this the author had three principal objects before him; the firſt was to give a conciſe view of every thing which appears intereſting in natural hiſtory, reſpecting the origin, developement, and reproduction of organized bodies; the ſecond was to confute the two different ſyſtems founded upon the Epigeneſis; and the third was to explain the ſyſtem of Germs, indicate the ground upon which it was founded, its correſpondence with facts, and the conſequences reſulting from it. This work was received with much ſatisfaction by natural philoſophers. The Academy of Berlin, which had propoſed the ſame ſubject as a prize queſtion for 1761, declared that they conſidered the treatiſe as the offspring of cloſe obſervation and profound reaſoning; and that the author would have had an indubitable right to the prize, if he had confined his labours to the preciſe ſtatement of the queſtion. It muſt alſo be recorded, to the honour of the great *Maleſherbes*, that he reverſed the interdict which the public cenſor had laid upon this book, under the pretext that it contained dangerous principles.

The Contemplation of Nature appeared in 1764. In this work the author firſt enlarged upon the common conceptions entertained concerning the exiſtence and perfections of God; and of the order and uniformity obſervable in the univerſe. He next deſcends to man, examines the parts of his compoſition, and the various capacities with which he is endowed. He next proceeds to the plants; aſſembles and deſcribes the laws of their economy; and, finally, he examines the inſects, indicates the principal circumſtances in which they differ from larger animals, and points out the philoſophical inferences that may legitimately be deduced from theſe differences; and he concludes with obſervations reſpecting the induſtry of inſects. This work being of a popular nature, the author ſpared no pains in beſtowing upon it thoſe ornaments of which it was ſuſceptible. The principles which he thus diſcovered and explained, induced him to plan *a ſyſtem of moral philoſophy;* which, according to his ideas, conſiſted ſolely in the obſervance of that relation in which man is placed, reſpecting all the beings that ſurround him. The firſt branch would have comprehended, various means which philoſophy and the medical ſcience have diſcovered for the prevention of diſeaſe, the preſervation and augmentation of the corporeal powers, and the better exertion of their force: in the ſecond, he propoſed to ſhew, that natural philoſophy has a powerful tendency to embelliſh and improve our mind, and augment the number of our rational amuſements, while it is replete with beneficial effects reſpecting the ſociety at large. To maniſeſt the invalidity of opinions, merely hypothetical, he undertook, in the third place, to examine, whether there were not truths within the compaſs of human knowledge, to which the moſt ſceptical philoſopher muſt be compelled to yield his conſent, and which might ſerve as the baſis of all our reaſonings concerning man and his various relations. He then would have directed his attention to a firſt cauſe, and have manifeſted how greatly the idea of a Deity and Supreme Lawgiver favoured the concluſions which reaſon had drawn from the nature and properties of things: but it is deeply to be regretted that his health, impaired by inceſſant labour, would not permit him to complete the deſign.

His laſt publication was the *Palingeneſis*, which treats of the prior exiſtence and future ſtate of living beings.

Of his publications in natural hiſtory, thoſe deemed the moſt excellent are, his Treatiſe on the beſt Means of preſerving Inſects and Fiſh in Cabinets of Natural Hiſtory; a diſſertation on the Loves of the Plants; ſundry pieces on the Experiments of *Spallanzani*, concerning the Reproduction of the Head of the Snail; a Diſſertation on the *Pipa*, or Surinam Toad; and different Treatiſes on Bees.

In the year 1783 he was elected honorary member of the Academy of Sciences at Paris; and of the Academy of Sciences and the Belles Lettres at Berlin.

Much of his time was employed in a very extenſive correſpondence with ſome of the moſt celebrated natural philoſophers and others. Of this number were *Reaumur*, *De Geer* the Reaumur of Sweden, *Du Hamel*, the learned *Haller*, the experimental philoſopher *Spallanzani*,

lanzani, Van Swieten, Merian, and that ornament of Switzerland the great *Lambert.* He entertained, however, the utmoſt averſion to controverſy. He thought that no advantage to be obtained by it could compenſate for the loſs of that repoſe which he valued, with Newton, as the *rem prorſus ſubſtantialem.* He never anſwered remarks that were made to the prejudice of his writings, but left the deciſion with the public; yet, ever ready to acknowledge his errors, he was ſincerely thankful to every one who contributed to the perfection of his works. He was uſed to ſay, that one confeſſion, *I was in the wrong*, is of more value than a thouſand ingenious confutations.

His literary occupations, and the care he was obliged to take of his health, prevented him from travelling. He delighted in retirement, and every hour was occupied in the improvement of his mind. The laſt 25 years of his life were ſpent in the ſame rural ſituation where he had paſſed the greater part of his early days; yet notwithſtanding the purſuit of literature was his ſupreme delight, he never refuſed to ſuſpend his ſtudies, when the good of his country ſeemed to demand his ſervices.

He was choſen in 1752 member of the Grand Council in the republic of Geneva; and he aſſiſted regularly at their deliberations till the year 1768, where he diſtinguiſhed himſelf by his eloquence; his moderation, united with firmneſs; by his good ſenſe and penetration in caſes of difficulty; and by the zeal with which he endeavoured to reclaim his fellow-citizens to that ancient ſimplicity of manners which had been ſo conducive to the welfare of the ſtate, and to the love of virtue, ſo eſſential to the exiſtence of genuine liberty. His conduct, in every caſe, was conſiſtent with his principles. He took no pains to accumulate wealth, but remained ſatisfied with a fortune equal to his moderate wants, and to the exerciſe of his benevolence. The perfect correſpondence between his extenſive knowledge and virtuous deeds procured him univerſal eſteem.

In the year 1788 evident ſymptoms of an *hydrops pectoris* manifeſted themſelves; and from this time he gradually declined. He ſuſtained his indiſpoſition with unremitted cheerfulneſs and compoſure. After various fluctuations, uſual in that complaint, he died on the 20th of May 1793, in the 73d year of his age; retaining his preſence of mind to the laſt moment, adminiſtering comfort to ſurrounding friends and relatives, and attempting to alleviate the diſtreſs of his diſconſolate wife, in whoſe arms he expired.

As a demonſtration of the high value placed upon his labours and talents by the literati, we have only to remark, that he was member of moſt of the learned ſocieties of Europe.

BOOK KEEPING, is an art of which the importance is univerſally known; and as commonly practiſed, it has been ſufficiently explained in the Encyclopædia. But ſince that article was written, a great improvement has been introduced into the art, or rather a new method of book-keeping has been invented, by Mr EDWARD THOMAS JONES, of the city of Briſtol, accountant, who calls it the *Engliſh ſyſtem of book-keeping;* and thinks that by it accounts may be more regularly kept, and errors in accounts more eaſily detected, than by any other method hitherto known. We are much inclined to be of his opinion; and ſhall therefore lay before our readers his deſcription of this method, as we find it in the ſpecification of the patent which was granted to him January 26, 1796.

The Engliſh Syſtem of Book-Keeping requires three books, called a *day-book* or *journal*, an *alphabet*, and a *ledger*, which muſt be ruled after the following method, *viz.* the day-book to have three columns on each page, for receiving the amount of the tranſactions; one column of which to receive the amount of debits and credits, one column to receive the debits only, and one column to receive the credits only; or it may be ruled with only two columns on each page, one column to receive the amount of the debits, and one column to receive the amount of the credits. There muſt alſo be on each page of the day-book four other columns ruled, two on the left ſide next the amount of the debits, and two on the right ſide next the amount of the credits, for receiving the letter or mark of poſting, and the page of the ledger to which each amount is to be poſted.

The alphabet need not be ruled at all, but muſt contain the name of every account in the ledger, the letter that is annexed to it as a mark of poſting, and the page of the ledger.

The ledger muſt be ruled with three, four, five, or ſeven columns on each page, as may be moſt agreeable, for receiving the amounts of the different tranſactions entered in the day-book. And the proceſs for uſing theſe books, or making up books of accounts on this plan, is as follows.

When a perſon enters into trade, whether by himſelf or with copartners, he muſt have an account opened with himſelf in the ledger; entering firſt in the day-book, and then to the credit of his account in the ledger, the amount of the property he advances into trade: The account may be headed either with his name only, or elſe called his ſtock-account.

If you buy goods, give the perſon credit of whom you purchaſe; when you ſell goods, debit the perſon to whom ſaid goods are ſold. If you pay money, debit the perſon to whom paid, not only for what you pay, but alſo for any diſcount or abatement he may allow, and give the caſhier credit for the neat amount paid. If you receive money, credit the perſon of whom you receive it, not only for what he pays, but alſo for any diſcount or abatement you may allow, and debit the caſhier for the neat amount received; taking care in theſe entries to have nothing myſterious or obſcure, but merely a plain narrative of the fact, introducing not one uſeleſs word, and avoiding every technical term or phraſe except the words debit and credit, which are full and comprehenſive, and the only terms that are applicable to every tranſaction, and may be affixed to every entry.

But as a hurry of buſineſs will ſometimes take place in almoſt every counting-houſe, which may cauſe the entries to be made to the debit inſtead of the credit of an account in the day-book, and to the credit inſtead of the debit, Mr Jones has endeavoured as much as poſſible to counteract the evil, by having only one column for receiving the amount of every tranſaction, whether debits or credits, at the inſtant of making the entry; and, for the convenience of ſeparating the debits from the credits, previous to poſting, which is neceſſary to prevent confuſion and perplexity, he has two other columns on the ſame page; that on the left ſide into which the amount of every debit muſt be carefully entered, and that on the right for the amount of the credits, which columns muſt be caſt up once a month. The column of debits and credits of itſelf forming one amount; the column for the debits producing a ſecond amount; and the column of credits a third amount; which ſecond and third amounts, added together, muſt exactly agree with the firſt amount, or the work is not done right.

By this means the man of buſineſs may obtain monthly ſuch a ſtatement of his affairs as will ſhow how much he owes for that month, and how much is owing to him; and the debits being added together for any given time, with the value of the ſtock of goods on hand, will, when the amount of the credit is ſubtracted therefrom, ſhew the profits of the trade.

Our author now proceeds to the proceſs of poſting; which begins with opening an account in the ledger with every perſon to whoſe debit or credit there has been an entry made in the day-book; affixing to each account a letter, which is to be uſed as a mark of poſting. The perſon's name, place of abode, and the folio of the ledger, muſt then be entered in the alphabet, with the ſame letter prefixed to each name as is affixed to the account in the ledger. Next the page of the ledger on which each account is opened (and which will be ſeen in the alphabet) muſt be affixed to each amount in the day-book, in the column for that purpoſe. The date and amount of each debit muſt then be poſted in the columns for receiving it in the ledger, on the left or debit ſide of that account to which it relates; entering, as a mark of poſting in the day-book, againſt each amount, the ſame letter that is affixed to the account in the ledger, to which ſaid amount may be poſted. Obſerving that the debits of January, February, March, &c. muſt be poſted into the column for thoſe months in the ledger, and the credits muſt alſo be poſted in like manner, filling up each account in the centre, at the expiration of every month, with the whole amount of the month's tranſactions; thus having in a ſmall ſpace, the whole ſtatement of each perſon's account for the year; in the columns to the right and left the amount ſeparately of each tranſaction; and in the centre a monthly ſtatement.

Having deſcribed the proceſs of this method of book-keeping, he thus ſhews how to examine books kept by this method, ſo as to aſcertain, to an abſolute certainty, if the ledger be a true repreſentation of the day-book; *i. e.* not only if each tranſaction be correctly poſted, as to the amount thereof, but alſo if it be rightly entered to the debit or credit of its proper account. This examination differs from the modes that have heretofore been practiſed, as well in expedition as in the certain accuracy which attends the proceſs; it being only neceſſary to caſt up the columns through the ledger debits and credits, according to the examples given; and the amount of thoſe columns, if right, muſt agree with the columns in the day-book for the ſame correſponding ſpace of time. Theſe caſtings ſhould take place once a month; and if the amounts do not agree, the poſting muſt then, but not elſe, be called over; and when the time, whether it be one, two, three, or four months, that is allotted to each column of the ledger is expired, the amount of each column ſhould be put at the bottom of the firſt page, and carried forward to the bottom of the next, and ſo on to the end of the accounts; taking care that the amount in the day-book, of each month's tranſactions, be brought into one groſs amount for the ſame time.

But although this proceſs muſt prove that the ledger contains the whole contents of the day-book, and neither more nor leſs, yet it is not complete without the mode of aſcertaining if each entry be poſted to its right account; which may be aſcertained by the following method. He has laid down a rule that a letter, which may be uſed alphabetically in any form or ſhape that is agreeable, ſhall be affixed to each account in the ledger, and the ſame letter prefixed to the names in the alphabet, theſe letters being uſed as marks of poſting, and affixed to each account in the day-book as it is poſted; it is only neceſſary therefore to compare and ſee that the letter affixed to each entry in the day-book is the ſame as is prefixed to the ſame name in the alphabet; a difference here ſhews of courſe an error, or elſe it muſt be right.

At the end of the year, or at any other time, when perſons balance their accounts, if there be no objections to the profits of the trade appearing in the books, the ſtock of goods on hand at prime coſt may be entered in the day-book, either the value in one amount, or the particulars ſpecified, as may be moſt expedient, and an account opened for it in the ledger, to the debit of which it muſt be poſted. The caſting up of the ledger muſt then be completed; and when found to agree with the day-book, and the amount placed at the bottom of each column, ſubtract the credits from the debits, and it will ſhew the profit of the trade; unleſs the credits be the greater amount, which will ſhew a loſs. In taking off the balances of the ledger, one rule muſt be obſerved, and it cannot be done wrong: As you proceed, firſt ſee the difference between the whole amounts of the credits and debits on each page for the year, with which the difference of the outſtanding balances of the ſeveral accounts on each page muſt exactly agree, or the balances will not be taken right. By this means every page will be proved as you proceed, and the balances of ten thouſand ledgers, on this plan, could not unobſervedly be taken off wrong.

BORDENTOWN, a pleaſant town in Burlington co. New-Jerſey, is ſituated at the mouth of Croſswicks Creek, on the E. bank of a great bend of Delaware River; 6 miles below Trenton, 9 N. E. from Burlington, by water, and 15 by land, and 24 miles N. E. from Philadelphia; and through this town, which contains about 100 houſes, a line of ſtages paſſes from New-York to Philadelphia. The ſecond diviſion of Heſſians was placed in this town, in December, 1776; and by the road leading to it, 600 men of that nation eſcaped, when Gen. Waſhington ſurpriſed, and made priſoners of 886 privates, and 23 Heſſian officers, at Trenton.—*Morſe.*

BOSCAWEN, a townſhip in Hillſborough co. New-Hampſhire, on the weſtern bank of Merrimack River above Concord; 43 miles N. W. of Exeter, and 38 S. E. of Dartmouth College; having 1108 inhabitants. Boſcawen Hills are in this neighborhood.—*ib.*

BOSCOVICH (Roger Joſeph), one of the moſt eminent mathematicians and philoſophers of the preſent age, was born, of virtuous and pious parents, on the 11th of May 1711, in the city of Raguſa, the capital

pital of a ſmall republic of the ſame name, lying on the eaſtern coaſt of the Adriatic Sea. At baptiſm, the name of Roger was given him, to which he added that of Joſeph when he received the ſacrament (A) of confirmation.

He ſtudied Latin grammar in the ſchools which were taught by the Jeſuits in his native city. Here it ſoon appeared that he was endued with ſuperior talents for the acquiſition of learning. He received knowledge with great facility, and retained it with equal firmneſs. None of his companions more readily perceived the meaning of any precept than he; none more juſtly applied general rules to the particular caſes contained under them. He announced his thoughts with great perſpicuity, and came ſoon to compoſe with propriety and elegance. His application was equal to his capacity, and his progreſs was rapid. At the beginning of the 15th year of his age, he had already gone through the grammar claſſes with applauſe, and had ſtudied rhetoric for ſome months. His moral behaviour had likewiſe been very good: he was reſpectful and obedient to his parents and maſters, affable and obliging to his equals, and exemplary in all the duties of religion. It was now time for him to determine what courſe he would ſteer through life; nor did he heſitate long in coming to a reſolution.

The Jeſuit fathers, by teaching the ſciences to youth, were very uſeful, and at the ſame time had a fine opportunity of obſerving their ſcholars and of drawing into their ſociety thoſe boys who ſeemed fit for their purpoſe. Such a ſubject as the young Boſcovich could not eſcape their attention. They ſhewed him particular kindneſs, to which he was not inſenſible. He had an ardent thirſt for learning; to advance in which he felt himſelf capable; and he thought he could nowhere have a better opportunity of gratifying this laudable inclination than in their order, in which ſo many perſons had ſhone in the republic of letters. Accordingly, with the conſent of his parents, he petitioned to be received among them; and his petition was immediately granted, becauſe it was deſired by thoſe to whom it was made.

It was a maxim with the Jeſuits to place their moſt eminent ſubjects at Rome, as it was of importance for them to make a good figure on that great theatre. Wherefore, as Roger's maſters had formed great expectations of him, they procured his being called to that city; whither he was ſent in the year 1725, and entered the noviceſhip with great alacrity. This noviceſhip was a ſpace of two years, in which the candidate made a trial of his new ſtate of life; and in the mean time his new ſuperiors obſerved him, and deliberated whether or not they would admit him into their body. During theſe two years, the novice was principally employed in exerciſes of piety, in ſtudying books of Chriſtian morality, and in becoming perfectly acquainted with the rules and conſtitutions of the order. After theſe two years were paſt, the Jeſuits were willing to retain Boſcovich, and he was no leſs deſirous of remaining with them. He therefore paſſed to the ſchool of rhetoric; in which, for two other years under the moſt expert maſters of the ſociety, young men perfected themſelves in the arts of writing and ſpeaking, which was of ſo great conſequence to perſons who were deſtined to treat ſo much with their neighbours. Here Boſcovich became perfectly well acquainted with all the claſſical authors, and applied with ſome predilection to Latin poetry.

After this he removed from the noviciate to the Roman College, in order to ſtudy philoſophy, which he did for three years. In order to underſtand the doctrine of phyſics, it was neceſſary to premiſe the knowledge of the elements of geometry, which is alſo otherwiſe proper for forming the mind, and for giving to it a true taſte for truth. Here it was that our young philoſopher came to be in his true element; and it now appeared how extremely fit his genius was for this kind of ſtudy. His maſter, though he was able and expert, inſtead of leading him on, was ſcarcely able to keep pace with him, and his condiſciples were left far behind. He likewiſe found the application of the mathematics to natural philoſophy pleaſant and eaſy. From all this, before the end of the three years, he had made a great advancement in phyſical and mathematical knowledge, and his great merit was generally acknowledged by his companions, and well known to his ſuperiors. He had already begun to give private leſſons on mathematics.

According to the ordinary courſe followed by the Jeſuits, their young men, after ſtudying philoſophy, were wont to be employed in teaching Latin and the belles lettres for the ſpace of five years, that ſo they might become ſtill better acquainted with polite learning, and arrive at the ſtudy of theology and the prieſthood at a riper age. But as Roger had diſcovered extraordinary talents for geometrical ſtudies, it was thought by his ſuperiors that it would be a pity to detain him from his favourite purſuits in a drudgery for which ſo many others were fit enough. He was therefore diſpenſed with from teaching thoſe ſchools, and was commanded to commence the ſtudy of divinity.

During the four years that he applied to that ſublime ſcience, he ſtill found ſome leiſure for geometry and phyſics; and even before that ſpace was ended, he was named profeſſor of his beloved mathematics.

He was now placed in an office for which he was ſuperlatively fit, and for which he had a particular predilection. Beſides having ſeen all the beſt modern productions on mathematical ſubjects, he ſtudied diligently the ancient geometricians, and from them learned that exact manner of reaſoning which is to be obſerved in all his works. Although he himſelf perceived eaſily the concatenation of mathematical truths, and could follow them into their moſt abſtruſe receſſes, yet he accommodated himſelf with a fatherly condeſcenſion to the weaker capacities of his ſcholars, and made every demonſtration clearly intelligible to them. When he perceived that any of his diſciples were capable of advancing faſter than the reſt, he himſelf would propoſe

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(A) For this article we are indebted to a dignified clergyman of the church of Rome, who was one of Boſcovich's favourite pupils.

his giving them private leſſons, that ſo they might not loſe their time; or he would propoſe to them proper books with directions how to ſtudy them by themſelves, being always ready to ſolve difficulties that might occur to them.

To the end that he might be the more uſeful to his ſcholars, he took time from higher purſuits to compoſe new elements of arithmetic, algebra, plain and ſolid geometry, and of plain and ſpheric trigonometry; and although theſe ſubjects had been well treated by a great many authors, yet Boſcovich's work will always be eſteemed by good judges as a maſterly performance, well adapted to the purpoſe for which it was intended. To this he afterwards added a new expoſition of conic ſections; in which, from one general definition, he draws, with admirable perſpicuity, all the properties of thoſe three moſt uſeful curves. He had meditated a complete body of pure and mixed mathematics, in which were to be comprehended treatiſes on muſic, and on civil and military architecture; but from accompliſhing this he was prevented by other neceſſary occupations.

According to the cuſtom of ſchools, every claſs in the Roman College, towards the end of the ſcholaſtic year, gave to the public ſpecimens of their proficiency. With this view Boſcovich publiſhed yearly a diſſertation on ſome intereſting phyſico-mathematical ſubject. The doctrine of this diſſertation was defended publickly by ſome of his ſcholars, aſſiſted by their maſter. At theſe literary diſſertations there was always a numerous concourſe of the moſt learned men in Rome. His new opinions in philoſophy were here rigorouſly examined and warmly controverted by perſons well verſed in phyſical ſtudies: but he propoſed nothing without ſolid grounds; he had foreſeen all their objections, anſwered them victoriouſly, and always came off with great applauſe and increaſe of reputation. He publiſhed likewiſe diſſertations on other occaſions; and theſe works, though ſmall in ſize, are very valuable both for the matter they contain, and alſo for the manner in which it is treated. The principal ſubjects of theſe diſſertations are the following: The ſpots in the ſun; the tranſit of mercury under the ſun; the geometrical conſtruction of ſpheric trigonometry; the aurora borealis; a new uſe of the teleſcope for the determination of celeſtial objects; the figure of the earth; the arguments made uſe of by the ancients to prove the rotundity of the ſame; the circles which are called oſculators; the motion of bodies projected in a ſpace void of reſiſtance; the nature of infinites and of infinitely little quantities; the inequality of gravity in different parts of the earth; the annual aberration of the fixed ſtars; the limits of the certainty to which aſtronomical obſervations can arrive; a diſcuſſion on the whole of aſtronomy; the motion of a body attracted by certain forces towards an immoveable centre in ſpaces void of reſiſtance; a mechanical problem on the ſolid of greateſt attraction; a new method of uſing the obſervation of the phaſes in the lunar eclipſes; the cycloid; the logiſtic and certain other curve lines; the forces that are called *living;* the comets; the flux and reflux of the ſea; light; whirlwinds; a demonſtration and illuſtration of a paſſage in Newton concerning the rainbow; the demonſtration and illuſtration of a method given by Euler regarding the calculation of fractions; the determination of the orbits of a planet by means of catoptrics, certain conditions of its motion being given; the centre of gravity and that of magnitude; the atmoſphere of the moon; the law of continuity, and the conſequences of it in the elements of matter and their forces; the law of the forces that exiſt in nature; lenſes and dioptrical teleſcopes; the perturbation which appears to be cauſed mutually by Jupiter and Saturn, and that chiefly about the time of their conjunction; the diviſibility of matter and the elements of bodies; the objective micrometer;—beſides other ſubjects of the like nature, of which he has treated in ſeparate pieces, or in communications inſerted in the tranſactions of literary ſocieties or academies, he being a member of thoſe that are moſt famous in Europe. It was in ſome of the abovementioned diſſertations that Boſcovich made known firſt to the world his ſentiments concerning the nature of body, which he afterwards digeſted into a regular theory, which is juſtly become ſo famous among the learned.

Father Noceti, another Jeſuit, had compoſed two excellent poems on the rainbow and the aurora borealis. Theſe poems were publiſhed with learned annotations by Boſcovich; in which, among other things, he with great ſagacity diſcovers errors in optics into which De Dominis, Kepler, and others, had fallen.

His countryman, Benedict Stay, after having publiſhed the philoſophy of Deſcartes in Latin verſe, attempted the ſame with regard to the more modern and more true philoſophy, and has executed it with wonderful ſucceſs, to the admiration of all good judges. The two firſt volumes of this elegant and accurate work were publiſhed with annotations and ſupplements by Boſcovich. Theſe ſupplements are ſo many ſhort diſſertations on the moſt important parts of phyſics and mathematics. Here is to be found a ſolution of the problem of the centre of oſcillation, to which Huygens had come by a wrong method; here he confutes Euler, who had imagined that the *vis inertiæ* was neceſſary in matter; here he refutes the ingenious efforts of Riccati on the Leibnitzian opinion of the forces called *living.* He likewiſe ſhews the falſehood of the mathematical prejudice, according to which the right line is conſidered as eſſentially more ſimple than curves, and makes it appear, that the notion of the ſaid right line is commonly accompanied with many paradoxes. He demonſtrates, by the doctrine of combinations, ſome beautiful theorems concerning the ſpace occupied by the ſmall maſſes of body, with many uſeful obſervations on ſpace and time.

Benedict XIV. who was a great encourager of learning, and a beneficent patron of learned men, was not ignorant how valuable a ſubject Rome poſſeſſed in Boſcovich; and this pope gave him many proofs of the eſteem he had for him. Two fiſſures which had been perceived in the cupola of the church of St. Peter's on the Vatican had occaſioned ſome alarm. The pope deſired Boſcovich and ſome other mathematicians to make their obſervations and give their opinion on the ſame. They obeyed, and their opinion was printed. They ſhewed that there was no cauſe to apprehend danger; but, for greater ſecurity, they propoſed certain precautions, which were adopted and put in execution.

The high opinion which the pope had formed of his talents, and the favour in which he was with Cardinal

Valenti, miniſter of ſtate, proved hindrances to his going to America, for which a propoſal was made to him by the court of Liſbon. Some differences had long ſubſiſted between Spain and Portugal concerning the boundaries of their reſpective dominions in that great continent; and John V. of Portugal wiſhed that Boſcovich would go over and make a topographical ſurvey of the country in diſpute. He was not unwilling to undertake ſuch a taſk, which was entirely to his taſte; and he was reſolved at the ſame time to meaſure a degree of the meridian in Brazil, which might be compared with that meaſured at Quito by the French academicians Bouguer and Condamine, with the Spaniards Ulloa and Doy. But the pope hearing of this propoſal, ſignified to the Portugueſe miniſter at Rome, that his maſter muſt needs excuſe him for detaining Boſcovich in Italy, where he had occaſion for him, and could by no means conſent to part with him.

Accordingly a commiſſion was given to Boſcovich by Benedict to correct the maps of the papal eſtate, and to meaſure a degree of the meridian paſſing thro' the ſame. This he performed with great accuracy, aſſiſted by F. Chriſtopher Maire an Engliſh Jeſuit, and likewiſe a great mathematician. Their map was engraved at Rome, and is perhaps the moſt exact piece of the kind that ever was printed, as all the places are laid down from triangular obſervations made by the ableſt hands. Boſcovich alſo publiſhed, in a quarto volume in Latin, an account of the whole expedition, which appeared at Rome in the year 1755, and was afterwards printed at Paris in French in the year 1770. Here he gives a detail of their obſervations and of the methods they followed, and likewiſe of the difficulties they encountered, and how they were ſurmounted. One of theſe embarraſſed them a good deal at the time, but was afterwards matter of diverſion to them and others. Some of the inhabitants of the Apeninnes, ſeeing them paſs from hill to hill with poles and ſtrange machines, imagined that they were magicians come among their mountains in ſearch of hidden treaſures, of which they had ſome traditions: and as tempeſts of thunder and hail happened about the ſame time, they ſuppoſed that theſe calamities were cauſed by the ſorceries of their new viſitants. They therefore inſiſted that Boſcovich and Maire ſhould depart; and it was not eaſy to convince them that their operations were harmleſs. In this work there is inſerted a deſcription of the inſtruments made uſe of in determining the extent of the degree of the meridian; and the whole work may be extremely uſeful to practical geometricians and aſtronomers.

In the year 1757 the republic of Lucca entruſted Boſcovich with the management of an affair which was to them of conſiderable importance. Between that republic and the regency of Tuſcany there had ariſen a diſagreeable diſpute concerning the draining of a lake, and the direction to be given to ſome waters near the boundaries of the two eſtates. The Luccheſe ſenate choſe our philoſopher to treat of this buſineſs on their part. He repaired to the ſpot, conſidered it attentively, and drew up a writing, accompanied with a map, to ſhew more clearly what appeared to him moſt equitable and moſt advantageous for both parties. In order to enforce his reaſons the more effectually, it was thought proper that he ſhould go to Vienna, where the emperor Francis I. who was likewiſe grand duke of Tuſcany, reſided. He was ſo ſuccefsful in this negociation, that he obtained every thing that Lucca deſired, and at the ſame time acquired great eſteem at the imperial court. In proof of this, the empreſs queen made his opinion be aſked concerning the ſtability of the Ceſarean library, and the repairs to be made in it; which he gave in writing, and it was received with thanks, as being very well grounded.

When he had concluded the affair which had brought him to Vienna, he foreſaw that, for a month or two, the ſnows in the Alps would not allow him to return to Italy. He therefore reſolved to employ that time in completing his ſyſtem of natural philoſophy, on which he had been meditating for the ſpace of thirteen years. He publiſhed his work on that great ſubject in the beginning of the year 1758, in the abovementioned city. We ſhall in the end give an account of that celebrated ſyſtem, and here go on with our narration.

On his return to Lucca, he not only met with the approbation of all he had done for the intereſt of the republic, but alſo the ſenate, in teſtimony of their gratitude, made him preſents, and inrolled him in the number of their nobility, which was the greateſt honour they had in their power to confer on him.

He, who was thus uſeful to foreigners, could not refuſe to be ſerviceable to his own country when an occaſion of being ſo offered itſelf. The Britiſh miniſtry had been informed, that ſhips of war, for the French, had been built and fitted out in the ſea-ports of Raguſa, and had ſignified their diſpleaſure on that account. This occaſioned uneaſineſs to the ſenate of Raguſa, as their ſubjects are very ſea-faring, and much employed in the carrying trade; and therefore it would have been inconvenient for them to have cauſed any diſguſt againſt them in the principal maritime power. Their countryman Boſcovich was deſired to go to London, in order to ſatisfy that court on the abovementioned head; and with this deſire he complied cheerfully on many accounts. His ſucceſs at London was equal to that at Vienna. He pleaded the cauſe of his countrymen effectually there, and that without giving any offence to the French, with whom Raguſa ſoon after entered into a treaty of commerce.

Boſcovich came to London the more willingly, as he was deſirous of converſing with the learned men of Britain. He was received by the preſident and principal members of the Royal Society with great reſpect; and to that great body he dedicated his poem on the eclipſes of the ſun and moon, which was printed on this occaſion at London, in the year 1760. This is one of his works on which he himſelf put the greateſt value, and it has been much eſteemed by the learned. An edition of it was publiſhed at Venice the year following, and a third at Paris, which is the moſt correct; a tranſlation of it into French has likewiſe been publiſhed at Paris. In this very elegant Latin poem he gives an exact compend of aſtronomy, which ſerves as an introduction to the ſubject; he then explains all that belongs to the doctrine of eclipſes, and their uſe in geography; he conſiders the phenomena that are obſerved in the eclipſes of the ſun, and likewiſe of the moon; he propoſes a theorem, which is his own, concerning the diſtribution of light refracted from the atmoſphere of the earth by the ſhadow of the moon, which happens in the lunar eclipſes ; he explains the phenomenon of the reddiſh colour which often appears in the moon when ſhe is eclipſed, of which a ſufficient explication had not before been given ; this the author draws from the fundamental doctrine of Newton's theory concerning light and colours ; and hence takes occaſion to give a clear idea of the principal conſequences of the ſaid theory. All this is clothed with a beautiful poetical dreſs, and is adorned with pleaſant epiſodes, not to mention the learned annotations which are ſubjoined. This poem was compoſed, for the moſt part, whilſt the author was in journeys, or by way of amuſement, when he was obliged to wait for the opportunities of making aſtronomical obſervations.

The fellows of the Royal Society invited Boſcovich to accompany ſome of their number to America, to obſerve the tranſit of Venus, which was to happen in the year 1762 ; but being otherwiſe engaged, he could not accept of that invitation. He intended, however, by all means to obſerve that remarkable phenomenon, and had fixed on Conſtantinople as a proper place for doing ſo. He was conducted thither in a Venetian man of war, and much honoured by one of the baylos of that republic, who commanded the veſſel ; but, to his great regret, they arrived too late. He returned, by land, in the company of the Engliſh ambaſſador ; and a relation of that journey was publiſhed in French and afterwards in Italian.

During theſe journeys, Boſcovich's place in the Roman College was well filled by ſome of thoſe whom he himſelf had trained up in mathematical learning. He was now called by the ſenate of Milan to teach mathematics in the univerſity of Pavia, with the offer of a very conſiderable ſalary. He and his ſuperiors thought proper to accede to this propoſal, and he was received without being ſubjected to any previous examination ; which was always obſerved, excepting in ſuch an extraordinary caſe, by the decrees of the univerſity. Here he taught, with great applauſe, for the ſpace of ſix years, having at the ſame time the care of the obſervatory of the Royal College of Brera. About the year 1770, the empreſs queen made him profeſſor of aſtronomy and optics in the Palatine ſchools of Milan ; requiring of him, however, that he ſhould continue to improve the obſervatory of Brera ; which, under his direction, became one of the moſt perfect in Europe.

Here he was extremely happy, teaching the ſciences, applying to his favourite ſtudies, and converſing and correſponding with men of learning and of poliſhed manners ; when an event happened which cauſed to him the moſt ſenſible affliction. In the year 1773, the ſociety to which he belonged, and to which he had been from his youth warmly attached, was, to his great regret and diſappointment, aboliſhed. They who had been Jeſuits were allowed no longer to teach publicly ; nor was there any exception made in favour of Boſcovich, neither (ſuch was his humour then) would he have accepted of it, though it had been offered him. Propoſals were made to him by ſeveral perſons of diſtinction ; and, after ſome deliberation, he choſe Paris for his place of abode ; to which he was induced by the circumſtance of his being intimately acquainted with the prime miniſter at that court. He had not been many months at Paris when the univerſity of Piſa ſent him an invitation to go thither, in order to profeſs aſtronomy. But the French miniſter, underſtanding this, declared to the miniſter of Tuſcany, that it was the intention of his moſt Chriſtian majeſty to make his dominions agreeable to Boſcovich, by giving him liberal appointments. In fact he was ſoon naturalized, and two large penſions were beſtowed on him ; the one as an honourable ſupport, to the end that he might proſecute his ſublime ſtudies at his eaſe and in affluence ; the other as a ſalary annexed to a new office, created in his favour, under the name of *Director of Optics for the Sea Service*, and with the ſole obligation of perfecting the lenſes which are uſed in achromatical teleſcopes.

At Paris he remained ten years, applying principally to optics, and much regarded, not only by the moſt reaſonable men of letters, but likewiſe by the princes and miniſters, both of France and of other nations. But the greateſt men are not exempt from being envied. Some of the French were diſpleaſed that a foreigner ſhould appear ſuperior to themſelves ; others of them could not forget that Boſcovich had diſcovered and expoſed their miſtakes. The irreligion which prevailed too much among thoſe who bore the name of philoſophers, was diſagreeable to him. Theſe, and other ſuch circumſtances, made him wearied of Paris, and he deſired to reviſit his friends in Italy ; for which purpoſe he obtained leave of abſence for two years.

The firſt place in Italy in which he made any ſtay was at Baſſano, a town in the territories of Venice. Here, mindful of his obligations, he printed what he had been preparing for the preſs during his ſtay in France ; and this compoſes five volumes in large octavo, and is a treaſure of optical and aſtronomical knowledge. The ſubjects treated of in theſe volumes are as follow : A new inſtrument for determining the refracting and diverging forces of diaphonous bodies ; a demonſtration of the falſehood of the Newtonian analogy between light and ſound ; the algebraic formulæ regarding the focuſes of lenſes, and their applications for calculating the ſphericity of thoſe which are to be uſed in achromatical teleſcopes ; the corrections to be made in occular lenſes, and the error of the ſphericity of certain glaſſes ; the cauſes which hinder the exact union of the ſolar rays by means of the great burning glaſſes, and the determination of the loſs ariſing from it ; the method of determining the different velocities of light paſſing through different mediums by means of two dioptrical teleſcopes, one common, the other of a new kind, containing water between the objective glaſs and the place of the image ; a new kind of objective micrometers ; the defects and inutility of a dioptrical teleſcope propoſed and made at Paris, which gives two images of the ſame object, the one direct, the other inverſe, with two contrary motions of moveable objects ; maſſes floating in the atmoſphere, as hail of an extraordinary ſize, ſeen on the ſun with the teleſcope, and reſembling ſpots ; the aſtronomical refractions, and various methods for determining them ; various methods for determining the orbits of comets and of the new planet, with copious applications of theſe doctrines to other aſtronomical ſubjects, and ſtill more generally to geometry and to the ſcience of calculation ; the errors, the rectifications, and the uſe of quadrants, of ſextants, of aſtronomical ſectors, of the meridian line, of teleſcopes called the inſtruments of tranſits, of the meridian, and of the parallactic machine ; the trigonometrical differential formulæ, which are of ſo much uſe in aſtronomy ; the uſe of the micrometrical rhombus, extended to whatever oblique poſition ; the error ariſing from refractions in uſing the aſtronomical ring for a ſundial, and the correction to be made ; the appearing and the diſappearing of Saturn's ring ; the methods of determining the rotation of the ſun by means of the ſpots, propoſed formerly by the author, and now perfected ; the greateſt exactneſs poſſible in determining the length of a pendulum oſcillating every ſecond of middle time by the compariſon of terreſtrial and celeſtial gravity ; a compend of aſtronomy for the uſe of the marine, containing the elements of the heavenly motions, and of the aſtronomical inſtruments to be explained to a prince in the courſe of one month ; a method for determining the altitude of the poles with the greateſt exactneſs, by means of a gnomon alone, where other inſtruments are not to be had ; the determination of the illuminated edge of the moon to be obſerved on the meridian ; a method of uſing the retrograde return of Venus to the ſame longitude, for determining the leſs certain elements of her orbit ; a method for correcting the elements of a comet, of which the longitude of the node is given, and the inclination of the orbit has been found nearly ; another method for the ſame purpoſe, and for finding the elliptical orbit, when the parabolic one does not agree with the obſervations ; a method for correcting the elements of a planet by three obſervations ; the projection of an orbit inclined in the plane of the ecliptic ; the projection of an orbit inclined in any other plane ; the calculation of the aberration of the ſtars, ariſing from the ſucceſſive propagation of light ; ſome beautiful theorems belonging to triangles, which are of great uſe in aſtronomy, reduced to moſt ſimple demonſtrations.

After having ſeen the impreſſion of theſe five volumes finiſhed, Boſcovich left Baſſano, made an excurſion to Rome, and viſited his old friends there and in other places of Italy. He then took up his abode at Milan, and applied to the reviſing of ſome of his old works, and to the compoſing of new ones. He ſet himſelf particularly to prepare annotations and ſupplements to the remaining two volumes of Stay's Modern Philoſophy, which he had not had time to publiſh ſooner, and which he lived not to publiſh.

He was happy at Milan in the neighbourhood of Brera, where was his favourite obſervatory ; and in the company of many friends, who were become the more dear to him by his long abſence from them. But he began to conſider, with grief, that his two years of abſence were drawing to an end. He was very unwilling to leave Italy and return to France. He thought of applying for a prolongation of his abſence ; he thought of making intereſt at the Imperial court for ſome honourable commiſſion, which might be a pretext to him for remaining at Milan ; but he was afraid that the propoſal of never returning to France might appear indelicate and ungrateful to a nation from which he was receiving conſiderable penſions. He apprehended that thoſe perſons at Paris who had before oppoſed him, would take occaſion to tax him with ingratitude, and that hence his reputation would be tarniſhed. Theſe, and other ſuch thoughts, occaſioned a great perplexity of mind, which was followed by a deep melancholy ; and this could not be alleviated by the advice and comfort of his friends, becauſe by degrees he became incapable of hearing reaſon, his ideas being quite confuſed, and his imagination diſordered. To this diſagreeable change the ſtate of his health perhaps contributed. A gout had been wandering for ſome time through his body, and he had caught a ſevere cold ; nor would he admit of medical aſſiſtance, of which he had always been very diffident. It may alſo be that his long and intenſe application had hurt the organs of the brain, which in ſome manner are ſubſervient to the uſe of reaſon as long as the ſoul is united to the body. Be that as it will, during the laſt five months of his life this great man, who had been ſo far ſuperior in reaſoning to his ordinary fellow creatures, was much inferior to every one of them who is endued with the right uſe of the underſtanding. He had indeed ſome lucid intervals, and once there were hopes of a recovery ; but he ſoon relapſed, and an impoſthume breaking in his breaſt, put an end to his mortal exiſtence. He died at Milan on the 13th of February 1787, in the 76th year of his age.

He was tall in ſtature, of a robuſt conſtitution, of a pale complexion. His countenance was rather long, and was expreſſive of cheerfulneſs and good humour. He was open, ſincere, communicative, and benevolent. His friends ſometimes regretted that he appeared to be too irritable, and too ſenſible of what might ſeem an affront or neglect, which gave himſelf unneceſſary uneaſineſs. He was always unſtained in his morals, obedient to his ſuperiors, and exact in the performance of all Chriſtian duties, as became a Catholic prieſt, and in the obſervance of the particular rules of his order. His great knowledge of the works of nature made him entertain the higheſt admiration of the power and wiſdom of their Creator. He ſaw the neceſſity and advantages of a divine revelation, and was ſincerely attached to the Chriſtian religion, having a ſovereign contempt of the preſumption and fooliſh pride of unbelievers ; and being fully perſuaded that we cannot make a more noble uſe of our underſtanding than by ſubjecting it humbly to the authority of the Supreme Being, who knows numberleſs truths far beyond the utmoſt limits of our narrow comprehenſion, and who may juſtly require our belief of any of them that he ſees fit to propoſe to us.

The death of our philoſopher, who truly deſerved that name, was heard with regret by the learned through Europe, and more than ordinary reſpect has been paid to his memory. At Raguſa funeral exequies were performed for him with great ſolemnity by order of the ſenate, who aſſiſted at them in a body ; on which occaſion an eloquent oration in praiſe of him was pronounced. By a decree of the ſame ſenate, a Latin inſcription to his honour, engraved on marble, was placed in the principal church of their city. Of this inſcription the following is a copy :

turning the navigation to Rome from Fiumicino to Maccareſe; a third on two torrents in the territory of Perugia; a fourth on the bulwarks on the river Panaro; a fifth on the river Sidone, in the territory of Placentia; a ſixth on the entrance into the ſea of the Adige. He wrote other ſuch works on the bulwarks of the Po; on the harbours of Ancona, of Rimini, of Magna Vacca, and Savona, beſides others, almoſt all which were printed. He had likewiſe received a commiſſion from Clement XIII. to viſit the Pomptin lakes, on the draining of which he drew up his opinion in writing, to which he added further elucidations at the deſire of Pius VI. On theſe occaſions he ſhowed how uſeful philoſophy may be to the public; and of this he gave another proof when it was referred entirely to his judgment to determine whether or not the cupola of the cathedral of Milan could bear the weight of a very high ſpire, which it was propoſed to raiſe on it, and which was actually erected according to his directions.

His application to obſtruſe ſtudies did not hinder him from paying ſome attention to what is more pleaſant. We have ſeen that he was a poet: he was alſo well acquainted with hiſtory, and particularly with that of the Greeks and Romans, and with their antiquities. He wrote a diſſertation on an ancient villa diſcovered in his time upon the Tuſculan Hill, and on an ancient dial found there, which diſſertation was publiſhed at Rome in a literary journal. He wrote likewiſe three letters on the obeliſk of Cæſar Auguſtus, two of which were printed with his own name, and the third under the name of another.

Beſides all theſe works that were given to the public in his lifetime, many writings of his remained in manuſcript in the hands of different perſons, and particularly with his friend M. Gaetani, and many more with Count Michael de Sorgo, a Raguſan ſenator, who inherited all his papers that were in his own hands at his death. Theſe, it is hoped, have either been already ſent to the preſs or will be ſo; as nothing came from the pen of Boſcovich which was not uſeful and deſerving to ſee the light.

IT now remains that we give an account of his THEORY OF NATURAL PHILOSOPHY; and in doing this we ſhall, in the *firſt* place, lay before our readers a view of this ſyſtem. We ſhall, in the *ſecond* place, relate, from what principles and by what ſteps it was deduced. We ſhall, *thirdly*, take notice of the principal objections made to it, and ſubjoin the author's anſwers to the ſame. We ſhall, *finally*, ſhew how happily it may be applied to explain the general properties of matter, as well as the particular qualities of all the claſſes of bodies, which have been examined according to what it teaches.

1
iew of
oſcovich's
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1. In this ſyſtem, therefore, the whole maſs of matter, of which all the bodies of the univerſe are compoſed, conſiſts of an exceeding great, yet ſtill finite, number of ſimple, indiviſible, inextended, atoms. Theſe atoms are endued with *repulſive* and *attractive* forces, which vary and change from the one to the other, according to the diſtance between them, in the following manner: In the leaſt and innermoſt diſtances they repel one another; and this repulſive force increaſes beyond all limits as the diſtances are diminiſhed, and is conſequently ſufficient for extinguiſhing the greateſt velocity, and for preventing the contact of the atoms. In the ſenſible diſtances, this force is *attractive*, and decreaſes, at leaſt ſenſibly, as the ſquares of the diſtances increaſe, conſtituting univerſal gravity, and extending beyond the ſphere of the moſt diſtant comets. Between this innermoſt repulſive force and the outermoſt attractive one, in the inſenſible diſtances, many varieties and changes of the force, or determination to motion, take place: for the repulſive force decreaſes as the diſtance increaſes. At a certain diſtance it comes to vaniſh entirely; and, when that diſtance is increaſed, attraction begins, increaſes, becomes leſs, vaniſhes; and the diſtance becoming greater, the force becomes repulſive, increaſes, leſſens, and vaniſhes as before. Many varieties and changes of this kind happen in the inſenſible diſtances, ſometimes more rapidly, ſometimes more ſlowly, and ſometimes one of the forces may come to nothing, and then return back to the ſame without paſſing to the other. For all this there is full room in the diſtances that are inſenſible to us, ſeeing the leaſt part of ſpace is diviſible *in infinitum*. Beſides theſe repulſive and attractive forces, our atoms have that *vis inertiæ* which is admitted by almoſt all modern philoſophers. Theſe atoms, endued with theſe forces, conſtitute the whole ſubſtance of Boſcovich's ſyſtem; which, however ſimple and ſhort it may appear to be, has numberleſs and very wonderful conſequences, as we ſhall ſee afterwards. But, that a more clear idea of the whole theory may be eaſily formed, we ſhall make uſe of a geometrical figure well accommodated to that purpoſe. The right line C′AC is an axis, from which, in the point A, is drawn the right line AB at right angles. AB is conſidered as an *aſymptote*; on each ſide of which the two curves, quite ſimilar and equal, DEFGHIKLMNOPQRSTVU on the one ſide, and D′E′F′G′ on the other, are placed. Now, if ED be ſuppoſed to be *aſymptotical*, and be extended, it will ſtill approach to BA, but will never come to touch it. This curve ED approaches to the axis C′C, comes to it in E, cuts it and departs to a certain diſtance in F, after which it again approaches the ſame axis and cuts it in G. In like manner it forms the arches GHI, IKL, LMN, NOP, PQL. At laſt it goes on in T*ps*V, which is aſymptotical, and approaches to the axis; ſo that the diſtances from it are in a duplicate reciprocal proportion of the diſtances from the right line BA. If from any points of the axis, as from *a*, *b*, *d*, we raiſe the perpendiculars *a g*, *b r*, *d h*, the ſegments of the axis A *a*, A *b*, A *d*, are called *abſciſſes*, and repreſent the diſtances of any two points of matter from one another; and the perpendiculars *a g*, *b r*, *d h*, are called *ordinates*, and exhibit the repulſive or attractive force, according as it lies on the ſame ſide with D, or on the other ſide of the axis.

5
The whole theory expreſſed by a geometrical curve.
Plate VI. fig. 6.

Now it is evident that, in this form of the curve line, the *ordinate* *a g* will be increaſed beyond whatever limits, if the abſciſs A *a* be leſſened likewiſe beyond whatever limits; that if this abſciſs be increaſed to A *b*, the *ordinate* will be leſſened, and will paſs into *b r*, which will ſtill be leſſened as it approaches from *b* to E, where it will come to nothing; that then, the axis being increaſed to A *d*, the *ordinate* will change its direction into *b h*, and, on the oppoſite ſide, will increaſe at firſt to F, then it will decreaſe through *i l* as far as G, where it will again vaniſh, and again change its direction in *m n* to the former, and that, in the ſame manner, it will vaniſh and change its directions in all the ſections I, L, N, P, R, until the *ordinates o p*, *v s*, become of a conſtant direction, and decreaſe, at leaſt ſenſibly, in a reciprocal duplicate proportion of the abſciſſes A *o*, A *v*. Wherefore, it is manifeſt, that by ſuch a curve are expreſſed our forces; at firſt *repulſive*, and increaſing beyond all limits, the diſtances being leſſened in like manner, and which decreaſe, the ſame diſtances being augmented; then vaniſh, change their direction, and become *attractive*; vaniſh again, and become *repulſive*; till at laſt, at ſenſible diſtances, they remain on the ſide oppoſite to D, and are *attractive* in a duplicate reciprocal proportion of the diſtances.

We may alſo obſerve, that the *ordinates* may increaſe or decreaſe rapidly, as in *y v*, *z t*, or ſlowly, as in *v x*, *z c*; and, conſequently, that the forces may increaſe or decreaſe in like manner. We may add, that the curve may return back without interſecting, or even touching, the axis, as in *f*, and may return after having touched the ſame axis.

Although this curve expreſſes very clearly the *repulſive* and *attractive* forces of our ſyſtem, yet, at firſt ſight, it may appear to be a complicated irregular line. But the author ſhews that his curve is uniform and regular, and may be expreſſed by one uniform algebraical equation; which it will be neceſſary for us to conſider, in order to give ſatisfaction to our readers, and to do juſtice to the theory.

3
The ſimplicity of this curve proved.

Wherefore, from what we have ſeen, the curve muſt have the following ſix conditions: *1ſt*, It muſt be regular and ſimple, and not compoſed of an aggregate of arches of different curves. *2dly*, It is neceſſary that it cut the axis C′AC in certain given points only, at two equal diſtances on each ſide AE′, AE, AG′, AG, and ſo on. *3dly*, That to every *abſciſs* an *ordinate* correſpond. *4thly*, That if we take equal *abſciſſes* on each ſide of A, they have equal *ordinates*. *5thly*, That the right line AB be an *aſymptote*, the area BAED being aſymptotical, and conſequently infinite. *6thly*, That the arches terminated by any two interſections may be varied at pleaſure, and recede to any diſtance from the axis C′AC, and approach at pleaſure to whatever arches of whatever curves, cutting them, touching them, or oſculating them, in any place and manner.

In order to find an algebraical formula expreſſing the nature of a curve line that would anſwer all theſe ſix conditions, let us call the ordinate *y*, the abſciſs *x*, and let it be made $x x = z$. Then let us take the values of all the abſciſſes AE, AG, AI, &c. with the negative ſign, and let the ſum of the ſquares of all theſe values be called *a*, the ſum of the products of every two ſquares *b*, the ſum of the products of every three, *c*, and ſo on; and let the product of all of them be called *f*, and the number of the ſame values *m*. All this being ſuppoſed, let it be made $z^{m} + a z^{m-1} + b z^{m-2} + c z^{m-3}$ &c. $+ f = \mathrm{P}$. If we ſuppoſe P equal to nothing, it is clear that all the roots of that equation will be real and poſitive; that is, the ſquares only of the quantities AE, AG, AI, &c. which will be the values of *z*; and therefore, as it is $x = \pm\sqrt{z}$, becauſe it is $x x = z$, it is likewiſe clear that the values of *x* will be both AE, AG, AI, poſitive, and A′E′, A′G′, &c. negative.

This being done, let any quantity be multiplied by *z*, providing it hath no common diviſor with P, leſt *z* vaniſhing, it likewiſe might vaniſh; and having made *x* an infiniteſim of the firſt order, it may become an infiniteſim of the ſame, or of a lower order, as will be whatever formula $z^{r} + g z^{r-1} + h z^{r-2}$ &c. $+ l$; which, being ſuppoſed equal to o, may have as many imaginary, and as many and whatever real roots, providing none of them be thoſe of AG, AE, AI, &c. either poſitive or negative. If then the whole formula be multiplied by *z*, let this product be called Q.

If we make $\mathrm{P} - \mathrm{Q}\, f = o$, this equation will ſatisfy the five firſt conditions above mentioned; and the value of Q being properly determined, the ſixth condition alſo may be complied with.

For, in the firſt place, ſeeing the value P and Q are made equal to o, they have no common root, and therefore no common diviſor. Hence this equation cannot be reduced to two by diviſion; and therefore it is not compoſed of two equations, but is ſimple, and therefore exhibits one ſimple continued curve, which is not compoſed of any others; which is the firſt condition.

Secondly, The curve thus expreſſed will cut the axis C′AC in all the points E′, G, I, &c. G′, &c. and in them only: for it will cut that axis only in thoſe points in which $y = o$, and in all of them. Moreover, where it will be $y = o$, it will alſo be $\mathrm{Q}\, y = o$; and therefore, becauſe of $\mathrm{P} - \mathrm{Q}\, y = o$, it will be $\mathrm{P} = o$. But this will happen only in thoſe points in which *z* will be one of the roots of the equation $\mathrm{P} = o$; that is, as we have ſeen above, in the points E, G, I, or E′, G, &c.: wherefore, only in thoſe points will *y* vaniſh, and the curve cut the axis. Again, that the ſame curve will cut it in all theſe points, is clear from this, that in them all it will be $\mathrm{P} = o$. Wherefore it will likewiſe be $\mathrm{Q}\, y = o$; but it will not be $\mathrm{Q} = o$, ſeeing there is no common root of the equations $\mathrm{P} = o$ and $\mathrm{Q} = o$: it muſt therefore be $y = o$, and the curve will cut the axis: and thus the ſecond condition is ſatisfied.

Beſides, whereas it is $\mathrm{P} - \mathrm{Q}\, x = o$, it will be $y = \frac{\mathrm{P}}{\mathrm{Q}}$: the abſciſs *x* being, however, determined, we will have a certain determinate quantity for *z*; and thus P, Q, will be determined, and the only two of the kind. Wherefore *y* alſo will be ſole and determined; and therefore to every abſciſs *z*, one only ordinate *y* will correſpond. This is the third condition.

Again, whether *x* be aſſumed poſitive or negative, providing it be of the ſame length, ſtill the value $z = xx$ will be the ſame, and therefore the values of both P and Q will be the ſame: wherefore *y* will ſtill be the ſame. Taking, therefore, equal abſciſſes *z* on both ſides of A, the one poſitive, the other negative, they will have equal correſponding ordinates. This is the fourth condition.

If *x* be leſſened beyond all limits, whether it be poſitive or negative, *z* likewiſe will be leſſened beyond all limits, and will become an infiniteſim of the ſecond order: wherefore, in the value P, all the terms will decreaſe *in infinitum*, except in *y*, becauſe all the reſt beſides it are multiplied by *z*; and thus the value P will be as yet finite. But the value Q, which has the formula multiplied by z, will be leſſened *in infinitum*, and will be an infiniteſim of the ſecond order: therefore $\frac{P}{Q} = y$ will be augmented *in infinitum*, ſo as to become an infinite of the ſecond order. Wherefore the curve will have the right line AB for an *aſymptote*, and the area BAED will increaſe *in infinitum*: and if the ordinate y be aſſumed poſitive on the ſide AB, and expreſs repulſive forces, the aſymptotic arch ED will lie on the ſame ſide AB. This is the fifth condition.

Now the value Q can be varied in infinite manners; ſo that ſtill the conditions for which it was aſſumed may be fulfilled; and therefore the arches of the curve intercepted by the interſections may be varied in infinite manners; ſo that the firſt five conditions of the curve may be implemented: whence it follows, that they may be ſo varied that the ſixth condition may alſo be anſwered.

For if there be given, however many, and whatever arches of whatever curve, providing they be ſuch that they recede always from the aſymptote AB, and thus no right line parallel to that aſymptote cut theſe arches in more than one point, and in them let there be taken as many points as you pleaſe, and as near one another; it will be eaſy to aſſume ſuch a value of P, that the curve ſhall paſs through all theſe points, and the ſame may be varied infinitely; ſo that ſtill the curve will paſs through all the ſame points.

Let the number of points aſſumed be what you pleaſe $= r$, and, from every one of ſuch points, let right lines be drawn parallel to AB, as far as the axis C′AC, which muſt be the ordinates of the curve that is ſought; and let the abſciſſes from A to the ſaid ordinates be called M^1, M^2, M^3, &c. and the ordinates $'N^1$, $'N^2$, $'N^3$, &c. Let there now be taken a certain quantity $Az^r + Bz^{r-1} + Cz^{r-2} + Gz$, and let this quantity be ſuppoſed equal to R. Then let another ſuch quantity T be aſſumed, ſo that z vaniſhing, whatſoever term of it may vaniſh, and ſo that there be no common diviſor of the value of P, and of the value of $R+T$; which may be eaſily done, ſeeing all the diviſors of the quantity P are known. Let it now be made $Q = R + T$, and then the equation of the curve will be $P - Ry - Ty = 0$. After this, let there be put in the equation $M1$, $M2$, $M3$, ſucceſſively for x, and $N1$, $N2$, $N3$, &c. for y; we will have a number of equations equal to r, which will contain the values of A, B, C. . . . . G, each of them of one dimenſion, in number likewiſe equal to r; and, beſides, we will have the given values of $M1$, $M2$, &c. $N1$, $N2$, $N3$, &c. and the arbitrary values which in T are the coefficients of z.

By theſe equations, which are in number r, it will be eaſy to determine the values A, B, C, ... G, which are likewiſe in number r, aſſuming the firſt equation, according to the uſual method, the value A, and ſubſtituting it in all the following equations; by which means the equations will become $r-1$. Theſe, again, by throwing out the value B, will be reduced to $r-2$, and ſo on until we come to one only; in which the value Q being determined by means of it, going back, all the preceding values will be determined, one by each equation.

The values A, B, C, ... G, being in this manner determined, in the equation $P - Ry - Ty = 0$, or $P - Qy = 0$, it is clear that, the values $M1$, $M2$, $M3$, &c. being ſucceſſively put for x, the values of the ordinate y muſt ſucceſſively be $N1$, $N2$, $N3$, &c. and, therefore, that the curve muſt paſs through theſe given points in thoſe given curves; and ſtill the value Q will have all the preceding conditions. For z being leſſened beyond whatever limits, every one of its terms will be leſſened beyond whatever limits, ſeeing all the terms of the value of T are leſſened which were thus aſſumed, and likewiſe the terms of the value R are leſſened, which are all multiplied by z; and, beſides this, there will be no common diviſor of the quantities P and Q, ſeeing there is none of the quantity P and $R+T$.

But if two of the neareſt of the points aſſumed in the arches of the curves, on the ſame ſide of the axis, be ſuppoſed to accede to one another beyond whatever limits, and at laſt to coincide, which will be done by making two M equal, and likewiſe two N equal; then the curve ſought will touch the arch of the given curve; and if three ſuch points coincide, they will *oſculate* it: nay, as many points as we pleaſe may be made to meet together where we pleaſe; and thus we may have *oſculations* of what order we pleaſe, and as near one another as we pleaſe, the arch of the given curve approaching as we pleaſe, and at whatever diſtances we pleaſe, to whatever arches of whatever curves, and yet ſtill preſerving all the ſix conditions required for expreſſing the law of the repulſive and attractive forces. And whereas the value of T can be varied in infinite manners, the ſame may be done in an infinite number of ways; and therefore a ſimple curve, anſwering the given conditions, may be found out in an infinite number of ways. *Q. E. F.*

What we have ſaid will, we hope, ſatisfy our readers, and eſpecially thoſe of them who are in the leaſt acquainted with high geometry, that Boſcovich's curve is ſimple, regular, and uniform; and that therefore the law of repulſive and attractive forces, expreſſed by it, is ſimple and regular.

II. If this ſyſtem were a mere hypotheſis, it would ſtill be very ingenious, and, from what we ſhall ſay afterwards, would ſtill be well adapted for explaining the phenomena of nature. But its author is far from looking upon it as an arbitrary ſuppoſition; he aſſures us that he was led to it by a chain of ſtrict reaſoning, from evident principles. We ſhall now give an abridgement of that reaſoning from his Diſſertations on the Law of *Continuity*, and from his Theory of Natural Philoſophy.

4
Proofs of the theory.

He tells us, then, that in the examination of Leibnitz's opinion of the *vires vivæ*, he came to conſider the colliſion of bodies, and took for example two equal bodies, A proceeding with ſix degrees of velocity, and B following with the velocity of 12: after the colliſion, they proceed jointly with the common velocity 9. Now, in the moment of colliſion, it either happens that A paſſes abruptly from the velocity 6 to the velocity 9, without paſſing through the velocity 7 and 8, and B paſſes from 12 of velocity to 9, without paſſing through 11 and 10; or elſe there muſt be ſome cauſe which accelerates the one and retards the other before they come to contact. In the firſt caſe, the law of continuity is broken; in the ſecond, immediate contact of bodies would be rejected. Maclaurin ſaw this difficulty, and mentioned it in his work on *Newton's Diſcoveries*, l. 1. c. 4. He, not having courage to recede from the common opinion, allowed a breach, in ſuch caſes, of the law of continuity; but Boſcovich maintains the univerſality of the law of continuity; and holds, that no bodies touch one another really and mathematically, but only phyſically and ſenſibly to us.

5 The law of continuity proved.

The law of continuity is that by which variable quantities, paſſing from one magnitude to another, paſs through all the intermediate magnitudes, without ever abruptly paſſing over any of them. This law Boſcovich proves to be univerſal, in the firſt place, from induction. Thus we ſee that the diſtances of two bodies can never be changed without their paſſing through all the intermediate diſtances. We ſee the planets move with different velocities and directions; but in this they ſtill obſerve the law of continuity. In heavy bodies projected, the velocity decreaſes and increaſes through all the intermediate velocities; the ſame happens with regard to elaſticity and magnetiſm. No body becomes more or leſs denſe without paſſing through the intermediate denſities. The light of the day increaſes in the morning and decreaſes at night through all the intermediate poſſible degrees. In a word, if we go through all nature, we ſhall ſee the law of continuity ſtrictly take place, if all things be rightly conſidered. It is true, we ſometimes make abrupt paſſages in our minds; as when we compare the length of one day with that of another immediately following, and ſay that the ſecond is two or three minutes longer or ſhorter than the former, paſſing all at once, in our way of ſpeaking, round the globe; but if we take all the longitudes, we ſhall find days of all the intermediate lengths. We likewiſe ſometimes confound a quick motion with an inſtantaneous one: thus, we are apt to imagine that the ball is thrown abruptly out of the gun; but, in truth, ſome ſpace of time is required for the gradual inflammation of the powder, for the rarefaction of the air, and for the communication of motion to the ball. In like manner, all the objections made againſt the law of continuity may be ſolved to ſatisfaction.

6 A breach of this law impoſſible.

But however ſtrong this argument from judgment may appear to be, yet Boſcovich goes farther, and maintains, that a breach of this law, in the proper caſes, is metaphyſically impoſſible. This argument he draws from the very nature of continuity. It is eſſential to continuity that, where one part of the thing *continued* ends and another part begins, the limit be common to both. Thus, when a geometrical line is divided into two, an indiviſible point is the common limit of both: thus time is *continued;* and therefore where one hour ends, another immediately begins, and the common limit is an indiviſible inſtant. Now, as all variations in variable quantities are made in time, they all partake of its continuity; and hence none of them can haſten by an abrupt paſſage from one magnitude to another, without paſſing through the intermediate magnitudes. As we cannot paſs from the ſixth hour to the ninth without paſſing through the ſeventh, and eighth; becauſe, if we did, there would be a common limit between the ſixth hour and the ninth, which is impoſſible; ſo likewiſe you cannot go from the diſtance 6 to the diſtance 9 without paſſing through the diſtances 7 and 8; becauſe, if you did, in the inſtant of paſſage you would be both at the diſtance 6 and at the diſtance 9, which is impoſſible. In like manner, a body that is condenſed or rarefied cannot paſs from the denſity 6 to the denſity 9, or *vice verſa*, without paſſing through the denſities 7 and 8; becauſe, in the abrupt paſſage, there would be two denſities, 6 and 9, in the ſame inſtant. The body muſt paſs through all the intermediate denſities. This it may do quickly or ſlowly, but ſtill it muſt evidently paſs through them all. The like may be ſaid of all variable quantities; and thence we may conclude, that the law of continuity is univerſal.

7 Objections to this law anſwered.

But, in creation, is there not an inſtance of an abrupt paſſage from *non-exiſtence* to *exiſtence?* No, there is not; becauſe before exiſtence a *being* is nothing, and therefore incapable of any ſtate. In creation, a *being* does not paſs from one ſtate to another abruptly; it paſſes over no intermediate ſtate: it begins to exiſt and to have a ſtate, and exiſtence is not diviſible. Do we not, at leaſt, allow of an abrupt paſſage from repulſive to attractive forces in our very theory itſelf? We do not. Our repulſive forces diminiſh, through all the intermediate magnitudes, down to nothing; through which, as a limit, they paſs to attraction. In the building of a houſe or ſhip, neither of them is augmented abruptly; becauſe the additions made to them are effected ſolely by a change of diſtances between the parts of which they are compoſed; and all the intermediate diſtances are gone through. The like may be ſaid of many other ſuch caſes; and ſtill the law of continuity remains firm and conſtant.

8 Impoſſibility of contact between bodies.

Let us now apply this doctrine to the caſe above mentioned of the colliſion of two bodies. We ſay that the body B cannot paſs from the velocity 6 to the velocity 9 without paſſing through the velocities 7 and 8; becauſe if it did, in the moment of contact of the two ſuperficies it would have the velocities 6 and 9. Now a body cannot have two velocities at the ſame inſtant. For if it had two *actual* velocities at the ſame time, it would be in two different places at the ſame time: if it had two different *potential* velocities or determinations to a certain velocity, it would be capable of being, after a given time, in two places at once—both which are impoſſible. It is therefore neceſſary that it go through the velocities 7 and 8, and through all the parts of them. What we have ſaid of the bodies A and B may be ſaid univerſally of all bodies. Therefore no two bodies in motion can come to immediate contact; but their velocities muſt undergo the ſucceſſive neceſſary change before contact. And as the velocity to be extinguiſhed may be increaſed beyond all limits, an adequate cauſe to effect this extinction muſt be admitted.

9 Repulſive forces

This naturally leads us to the interior repulſive forces of our ſyſtem. For the cauſe retarding the one body and accelerating the other muſt be a *force*, becauſe by this we mean a determination to motion; and it muſt be repulſive, becauſe it acts *from* the body; and it muſt increaſe beyond all limits, ſeeing the velocity of the incurring bodies may be increaſed beyond all limits. It muſt likewiſe be mutual, becauſe action and reaction are always equal, as may be proved by induction.

10 Inextended atoms.

From theſe repulſive forces Boſcovich deduces the inextenſion of his atoms: for this repulſion being common to all matter, muſt cauſe a perfect ſimplicity in the firſt elements of body. If theſe elements were extended, and conſequently compounded of particles of an inferior order, theſe particles might poſſibly be ſeparated, and then they might meet, and an abrupt paſſage from one velocity to another might take place, which we have excluded from nature by induction, and by a poſitive argument.

Beſides this, by rejecting the extenſion of the firſt elements of matter, we get rid at once of all the difficulties ariſing from continued extenſion in body, which have always perplexed the philoſophers, and have never been ſatisfactorily explained. If theſe elements of matter are extended, each of them may be divided *in infinitum*, and each part may ſtill be divided *in infinitum*. Can this diviſion be actually made by the power of God or not? Can there be one *infinite* in number greater than another? Can there be a *compound* without a *ſimple* of the ſame kind? Theſe difficulties regard not ſpace, which is no real being; but they would regard matter if it had continued extenſion. All theſe perplexities are removed by maintaining, as Boſcovich does, that the firſt elements of bodies are perfectly ſimple, and therefore inextended (A).

11 Attractive forces.

With regard to the exterior attractive forces of our ſyſtem, there can be no queſtion; ſeeing they conſtitute univerſal gravity, the effects of which we ſee and feel every day. But between the interior repulſive and exterior attractive forces we muſt admit many tranſitions from repulſion to attraction, and from attraction back to repulſion, in inſenſible diſtances, which are indicated to us by coheſion, fermentation, evaporation, and other phenomena of nature. And thus we have given, in ſhort, Boſcovich's proofs of his whole ſyſtem.

12 Objections to the ſyſtem anſwered.

III. This ſyſtem has been well received by the learned in Europe, and has contributed much to render its author famous; yet many objections againſt it have been propoſed. Some are ſtartled at the rejection of all immediate contact between bodies; and indeed Boſcovich is perhaps the firſt of mankind who advanced that opinion; but he allows that bodies approach ſo near to one another, as to leave no ſenſible diſtance between them: and his repulſive forces make the ſame impreſſion on the nerves of our ſenſes as the ſolid bodies could do. And therefore this opinion of his, however new, is nowiſe contrary to the teſtimony of our ſenſes. He only removes a prejudice which was before univerſal.

Some ſay, that they cannot even form an idea of an inextended atom, and that Boſcovich reduces all matter to nothing: but certainly extenſion is not neceſſary for the eſſence of a *being*, as muſt be allowed by all thoſe who hold that ſpirits are inextended. Becauſe all the bodies that fall under our ſenſes are extended, we are apt to look upon extenſion as eſſential to matter: but this error may be corrected by reflection, and an idea of an inextended atom may be formed, by conſidering the nature of a mathematical point, which is the limit of any two contiguous parts of a line.

Others again have ſaid, that if the elements of matter were void of extenſion, there would be no difference between body and ſpirit. But the difference between body and ſpirit does not conſiſt in the having or not having extenſion; but in this, that the atoms of matter are endued with repulſive and attractive forces, which ſpirit has not; and ſpirit has a capacity of thought and volition which bodies have not.

We may here obſerve, that among the ancients Zeno, and among the moderns Leibnitz, held, that the firſt principles of matter are inextended points. But both held this opinion with the inconſiſtency, that they maintained the continued extenſion of bodies, without ever being able to ſhew how continued extenſion could ariſe from inextended elements.

It has been objected likewiſe, that our repulſive and attractive forces are no better than the occult qualities of the Peripatetics. The like objection has been made to Newton's attraction: but the anſwer is eaſy. We obſerve the effects, and take notice of them; for them we muſt admit an adequate cauſe, without being able to determine, whether that cauſe is an immediate law of the Creator, or ſome mediate inſtrument that he makes uſe of for that purpoſe.

Some are unwilling to give up the idea of motion occaſioned by immediate impulſe: but can they ſhow a good reaſon why *ſome diſtance* may not occaſion motion as well as *no diſtance?* Theſe are the principal objections that have been made againſt the Boſcovichian ſyſtem.

13 Obſervations with regard to the curve.

IV. Before we proceed to the explication of phenomena by means of our theory, we muſt advert, that in the curve expreſſing this theory, the abſciſſes denote the diſtances between the atoms that are under conſideration; the ordinates give the preſent *force*, and the area between any two of theſe ordinates gives the ſquare of the velocity generated between them: the arches are either repulſive or attractive, according as they fall upon the ſame ſide with the aſymptotic curve EG, or on the oppoſite ſide.

14 Limits of coheſion, &c.

We muſt, in the next place, conſider the paſſages from one ſide of the axis to the other. Sometimes the paſſage is from repulſion to attraction, at other times from attraction to repulſion. The firſt are called *limits of coheſion*, becauſe a particle removed from that limit returns back to it; becauſe if it is removed to a greater diſtance it is attracted back, and if it is removed nearer it is repelled back. The ſecond are called *limits of non-coheſion;* becauſe a particle removed thence to a greater diſtance is repelled ſtill further, and if removed nearer it is attracted ſtill nearer. Of the firſt kind are E, I, N; of the ſecond are G, L. Likewiſe, when the curve touches the axis, it may either be an attractive part of the curve, or a repulſive part. Theſe limits may be nearer one another, or farther away; and the limits of coheſion may be ſtronger or weaker, according as the forces near them are greater or leſs.

Boſcovich conſiders minutely the effects of theſe varieties of limits and forces; firſt with regard to two points, then with regard to three and four, demonſtrat-

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(A) If a particle of matter is not extended, in what reſpect does it differ from a point of ſpace? Says Boſcovich, it is endowed with attractive and repulſive forces. What is this *it* before it is thus endowed? Does it *then* differ from a point of ſpace? We can form no notion of any ſuch difference. But a point of ſpace, conſidered as an individual, is diſtinguiſhed from another individual only by its ſituation; it is therefore immoveable, but matter is moveable. Have theſe forces, then, which make matter an object of ſenſe, any ſubſtratum, any thing in which they are inherent as qualities? What are the things which theſe qualities diſtinguiſh from each other as individuals?

26 Softneſs, flexibility, and elaſticity.

five arches within them ; others are ſofter, whoſe particles have thoſe arches of repulſion weaker. Some are flexible, the particles of which are placed in limits that have weak arches of repulſion and attraction on each ſide ; and if thoſe arches are ſhort, the particles may come to new limits of coheſion, and remain bent: but if the arches are longer, the former repulſion and attraction will continue to act, and bring back the body to its former poſition ; nay, in doing this with an accelerated velocity, the parts will paſs their former limits, and vibrate backwards and forwards, as may be ſeen in a bended ſpring. Thus elaſticity is accounted for.

27 Viſcoſity.

Viſcous bodies ſtand in the middle between ſolid and fluid. Their particles have leſs coheſion than the firſt, and more than the ſecond: they ſtick to other bodies by an attraction which their particles have from their compoſition. In like manner water itſelf ſticks to ſome bodies, and is repelled by others. All which ariſes from the different compoſition of the particles, which gives a variety of reſpective forces.

28 Organization.

What appears very wonderful in nature, is the compoſition of organic bodies. But if we conſider that particles may be ſo formed, that they may repel ſome and attract others, the whole of vegetation, nutrition, and ſecretion, may be underſtood, and follows from our ſyſtem. And as one particle may attract another in one part only, and repel it in every other ſituation, hence may be gathered the orderly ſituation of the particles in many cryſtallizations. The great variety of repulſive and attractive forces, or limits of coheſion, of the poſition of atoms, and of combinations of particles, will account for all theſe phenomena.

29 Chemical operations.

The chemical operations, which are ſo curious in themſelves, and ſo uſeful to ſociety, are well explained by Boſcovich's ſyſtem, and ſerve as a confirmation of its truth. Of this we ſhall give ſome inſtances. When ſome ſolids are thrown into ſome liquids, there happens to be a greater attraction between the particles of the ſolid and of the liquid than there is between the particles of the ſolid itſelf. Hence the particles of the ſolid are detached and ſurrounded by the fluid; this mixture retaining the form of globules, and therefore continuing to be fluid. This is called *ſolution.* But when the ſolid particles are covered to a certain depth, the attractive forces ceaſe on account of the different diſtances, and no more of the ſolid is detached. Then the fluid is ſaid to be *ſaturated.* If into this mixture another ſolid be put, the particles of which attract the fluid more ſtrongly, and perhaps at greater diſtances than the particles of the former; then the fluid will abandon the former and cleave to the latter, diſſolving them, and the particles of the former will fall to the bottom in the form of powder, into which they had been reduced by the ſolution. This ſeparation is called *precipitation.* Perhaps rain ariſes from a precipitation of this kind, when the aqueous particles are left by the air, which is more ſtrongly attracted by ſome other particles floating in the atmoſphere.

Fluids of the ſame ſpecific gravity are eaſily mixed; and even though the ſpecific gravity be different, the particles of the one attract thoſe of the other, in ſuch a manner that they ſeem to form one fluid by a kind of ſolution. Nay, it happens, that two fluids mixed together form a ſolid, becauſe their particles come to be in the limits of coheſion. They may even occupy leſs ſpace than they did before, by being attracted into leſs diſtances between their parts.

Fermentation is a neceſſary conſequence of our ſyſtem. For when bodies, whoſe particles, by the variety of their compoſition, are endued with different forces, come to be mixed, there muſt ariſe an agitation of the parts, and an oſcillation among them ; ſometimes greater, ſometimes leſs, according to the nature of the particles. This agitation is ſtopped by the expulſion of ſome particles, by the intruſion of others into vacant ſpaces and by the impreſſion of external bodies ; but always there is a change in what remains, becauſe there is a new diſpoſition of particles.

30 Fire and fuſion, &c.

Fire conſiſts in a violent fermentation of ſulphureous matter, eſpecially when it meets with the matter of light in any quantity. This fermentation agitates ſtrongly the parts of other bodies, ſeparates them from one another, and often throws them into a ſtate of fuſion ; the coheſion between their parts being broken, and they being thrown into a circular motion. In this ſtate they may be often mixed together, ſo as to form one body ; they may be again ſeparated by the action of the ſame fire, which evaporates ſome of them ſooner, ſome later. Hence the art of ſmelting metals.

When, in the agitation occaſioned by fire, ſome of the particles are thrown out into an arch of repulſion, they may fly off and evaporate. Sometimes the whole body may be thrown into a ſtrong repulſion and volatilization, or a ſudden exploſion take place ; when, before the particles are near an equilibrium, a ſmall force may occaſion a great change ; as the foot of a bird may occaſion the fall of a great rock, which was before almoſt detached from a mountain. In evaporation, the bodies that remain aſſume a particular figure, as all ſalts do ; and this upon account of their particles having certain parts only that attract one another, and conſequently occaſion a particular diſpoſition. All theſe chemical operations evidently prove that there are in nature repulſive and attractive forces between the particles of bodies at ſmall diſtances; which greatly confirms our whole ſyſtem.

31 Light.

Boſcovich holds, that light is an *effluvium,* emitted with great velocity from the luminous bodies by a ſtrong repulſion. He explains all the moſt remarkable properties of this extraordinary matter according to his own principles, and that with great acuteneſs. On this ſubject it is obſervable, that Newton ſaw the neceſſity of admitting repulſive forces for the reflexion of light, which extend at ſome diſtance from the reflecting ſurface, and therefore reſemble the repulſive forces of our theory.

32 Electricity and magnetiſm.

Our author gives likewiſe a probable explication of electricity, according to Franklin's ingenious hypotheſis, and likewiſe of magnetiſm, deducing the whole of the appearances from various attractions and repulſions. He ſuppoſes that fire and the electrical fluid differ only in this, that fire is in actual fermentation, and not ſo the electrical fluid.

33 Senſation.

Finally, he explains our bodily ſenſations, in which he agrees pretty much with other philoſophers ; excepting in this, that what they attribute to the immediate contact of bodies, or of certain particles emitted from them, he aſcribes to attractions and repulſions ; which indeed are particularly fit for cauſing that motion in our nerves, which is ſuppoſed to take place in the organs of ſenſation, and to be thence communicated to the brain.

34
Reconciliation of this with other ſyſtems,

It is to be obſerved, that although Boſcovich maintains, that the very firſt elements of matter are void of extenſion; yet he allows, that of theſe elements, combined in a certain manner, may be formed extended particles of various figures, the parts of which may be ſo coherent as to be inſeparable by any power in nature. By theſe means the opinion of thoſe philoſophers who are ſo fond of extended particles, may be in ſo far gratified. Nay, the Peripatetics may, if they pleaſe, adopt Boſcovich's inextended atoms for their *Materia Prima* without any inconſiſtency; and his repulſive and attractive forces may ſerve for their *ſubſtantial forms*. And as God can make impreſſions on our ſenſes independently of the atoms, their abſolute accidents may in ſome ſenſe be admitted. Nor would ſome ſuch extraordinary exertions of Divine Power favour idealiſm in the ordinary courſe of nature.

35
Eſpecially that of Newton.

But what is of more conſequence, it is more than probable, that had Newton lived to be acquainted with the Boſcovichian theory, he would have paid to it a very great regard. This we may conjecture from what he ſays in his laſt queſtion of optics; where, after having mentioned thoſe things which might be explained by an attractive force, ſucceeded by a repulſive one on a change of the diſtances, he adds, "And if all theſe things are ſo, then all nature will be very ſimple, and conſiſtent with itſelf, effecting all the great motions of the heavenly bodies by the attraction of gravity, which is mutual between all thoſe bodies, and almoſt all the leſs motions of its particles by another certain attractive and repulſive force, which is mutual between thoſe particles." And a little after, treating of the elementary particles, he ſays: "Now it ſeems that theſe elementary particles not only have in themſelves the *vis inertiæ*, and thoſe paſſive laws of motion which neceſſarily ariſe from that force, but that they likewiſe perpetually receive a motion from certain active principles; ſuch as gravity, and the cauſe of fermentation, and of the coheſion of bodies. And I conſider theſe principles, not as occult qualities, which are feigned to flow from the ſpecific forms of things, but as univerſal laws of nature, by which the things themſelves were formed. For that truly ſuch principles exiſt, the phenomena of nature ſhew, although what may be their cauſes has not as yet been explained. To affirm that every ſpecies of things is endued with ſpecific occult qualities, by which they have a certain power, is indeed to ſay nothing; but to deduce two or three general principles of motion from the phenomena of nature, and then to explain how the properties and action of all corporeal things follow from thoſe principles, this truly would be to have made a great advancement in philoſophy, although the cauſes of thoſe principles were not as yet known. Wherefore I do not heſitate to maintain the aboveſaid principles of motion, ſeeing they extend widely through all nature." From this paſſage we may ſafely conclude, that the great Britiſh philoſopher would have been highly pleaſed, had he ſeen all nature ſo well explained by the one ſimple law of forces propoſed by the Raguſan.

36
Compariſon of this ſyſtem to the key of a cypher.

Boſcovich himſelf was ſo fully convinced of the truth of his ſyſtem, that he was wont to make uſe of the following compariſon: When a letter has been written in occult characters, and we are endeavouring to decypher it, we make various ſuppoſitions of alphabets; and when we have found one according to which the whole letter comes to have a reaſonable meaning, agreeable to all the circumſtances of time, place, perſons, and things, we can entertain no doubt of our having diſcovered the true key of the cypher—ſo, ſaid he, my ſyſtem explains ſo well all the phenomena to which it has been properly applied, that I muſt flatter myſelf that I have diſcovered the true key of nature.

37
Exiſtence of God.

The being accuſtomed to contemplate ſo deeply the univerſe and the materials of which it is compoſed, made Boſcovich ſee moſt clearly the evident neceſſity of admitting an all powerful, intelligent, ſelf-exiſtent Being, for the creation of thoſe materials, and for the arrangement of them into their preſent beautiful form. He was at a loſs to find words ſtrong enough to expreſs his ſurpriſe, that there ſhould be any man, not to ſay any one pretending to the name of philoſopher, who could be ſo deaf as not to hear the voice of nature loudly proclaiming its Author from all, even the leaſt of its parts. He gives us his ſentiments on this, the moſt important of all ſubjects, in the appendix to his *Theoria*, in which he treats of God and of the ſoul of man.

38
The worl cannot be the effect chance;

There, in the firſt place, he ſhows the abſurdity of their opinion, who maintain that this world may have been the work of *chance*, the effect of a jumble of ſelf-exiſtent, ſelf-moving atoms: becauſe chance is an empty word without a real meaning. Whatever exiſts has its determinate cauſe, and can only be called *fortuitous* by us on account of our ignorance of that cauſe. Beſides this, though the number of atoms compoſing this world is finite, yet their poſſible combinations are many times *infinitely infinite*: for they may be placed in infinite places of an infinite line; of theſe lines there is an infinite number in every *plane*, and of theſe planes there is an infinite number in ſpace. Again, theſe points may have an infinite number of velocities in an infinite number of directions. From all this it is evident, that the combinations in which the points of matter may be, is infinite in a high degree, whereas *duration* can be infinite in only one dimenſion. Hence it is infinitely improbable that ever the preſent combination of things could come out by chance. And this is ſo much the more infinitely improbable, becauſe the diſorderly, chaotic combinations are infinitely more than the regular ones. The whole of matter might roll about in a blind motion for a boundleſs eternity, without ever being capable to produce one ſingle muſhroom.

Moreover, had matter been in motion from all eternity, every atom would have deſcribed an infinite line, and then a part of that line would be aſſignable at an infinite diſtance from the point of ſpace in which the atom is at preſent: but an infinite line can never be run over; therefore the atom could never have come to its preſent place; and therefore the ſuppoſition is abſurd. Nothing ſucceſſive can be eternal with a *paſt* eternity, though it can continue without end. God alone can be eternal and actually infinite, but his eternity and infinity are beyond our comprehenſion.

39
Nor have exiſted from eternity.

Neither can the world have exiſted of itſelf in any thing like to its preſent form from all eternity; for matter is perfectly indifferent to numberleſs ſtates, and to its preſent ſtate it muſt be determined. This preſent ſtate is perfectly incapable of determining itſelf, becauſe this determination muſt be previous to its exiſtence. It muſt be determined by the preceding ſtate, which is alſo incapable of determining itſelf, and for its determination we muſt have recourſe to the ſtate before. Thus, though we go back to eternity, we ſhall ſtill find a nullity of determination: now an infinite ſum of *nothing* is *nothing;* and therefore as the preſent ſtate of things could have no determination, it could not poſſibly exiſt.

It is therefore evident that there muſt be a Determiner extrinſic to the material world. This Determiner muſt have an infinite knowledge of all the poſſible combinations, and an infinite elective creative power to chuſe and create freely the combination he pleaſed, in that point of eternity that he choſe, with all the numberleſs circumſtances that are agreeable to him.

40 Attributes f God which ap- ear in the reation.

And here what a vaſt field of contemplation is laid open to a philoſophic mind! What a truly infinite knowledge was requiſite to foreſee ſo many ends, and ſo many means requiſite for obtaining thoſe ends, as are contained in the creation! Let us conſider light, for example, which was to be emitted for ſo many ages from ſo many luminous bodies, with ſo great velocity, ſo as to penetrate ſo many mediums with different degrees of reflectibility and refrangibility, with ſo many other wonderful qualities; at the ſame time ſo many bodies were to be perfectly fitted for reflecting this light in a certain manner, and the animal eye was to be ſo formed as to have a picture of viſible objects painted on the bottom of it.—How many particular combinations were neceſſary for all this? What ſhall we ſay of the ſo many herbs, flowers, trees, and animal bodies as there are on this our earth? All their kinds and ſpecies, all the ſeries of their individuals, all their parts and particles, were foreſeen, intended, and contrived, by one act of the Divine Mind. Again, how wonderful are the heavenly bodies, of what ſurpriſing magnitude, moving in the moſt beautiful order, at an immenſe diſtance from one another? To ſay nothing of the numberleſs creatures that are beyond the reach of the beſt teleſcope, or below that of the microſcope. He who reflects ever ſo little on theſe things, muſt neceſſarily ſee the moſt evident proofs of an infinite power, wiſdom, and providence; and he muſt be filled with admiration and awful reſpect for the Creator and Ruler of the univerſe.

41 Natural re- igion.

Nor are we unconcerned ſpectators of this grand ſcene. God has been pleaſed to make us enter deeply into his great plan of creation. He ſingled us out among an infinite number of poſſible human beings, in order to call us into exiſtence at a fixed period; and he has made a vaſt number of his creatures contribute to the formation of theſe wonderful machines, our bodies, as likewiſe to our nouriſhment, to our preſervation, to our neceſſities, conveniences, and gratifications. Every moment that we exiſt we are enjoying a great number of benefits, expreſsly deſigned for us by that Supreme Being. This evidently demands from us the higheſt degree of gratitude, love, and obedience.

42 Revelation.

Let us go a ſtep ſtill farther: Is it not very reaſonable to ſuppoſe, that our God, who affords us ſo many inſtances of his beneficence towards us in the natural order, will alſo, out of compaſſion to our weakneſs and ignorance, have favoured us with a more full and explicit manifeſtation of himſelf, of our duties towards him, and of his intentions concerning us? According to Boſcovich and all true philoſophers, reaſon itſelf alone, and true philoſophy, point out to us the probability at leaſt of God's having given us a ſtill better and ſurer guide, by whoſe direction we may attain to that perfect happineſs which we naturally thirſt after, and to which we muſt have been deſigned by our Maker. This is probable from reaſon alone; and of this great fact we are aſcertained by unqueſtionable authority.

BOSHMEN have been generally deſcribed as a diſtinct race of Hottentots, who are enemies to the paſtoral life, (ſee *Boshies-Men*, Encycl.) This M. Vaillant affirms to be a miſtake; and we think he has completely proved that it is ſo. "Theſe infamous wretches (ſays he) do not form a particular nation, nor are they a people who have had their origin in the places where they are now found. *Boſhmen* is a name compoſed of two Dutch words, which ſignify *buſh-men*, or *men of the woods;* and it is under this appellation that the inhabitants of the Cape, and all the Dutch in general, whether in Africa or America, diſtinguiſh thoſe malefactors or aſſaſſins who deſert from the colonies, in order to eſcape puniſhment. In a word, they are what in the Britiſh and French Weſt India iſlands are called *Maroon Negroes.* Theſe Boſhmen, therefore, far from being a diſtinct ſpecies, are only a promiſcuous aſſemblage of mulattoes, negroes, and maſtizos, of every ſpecies, and ſometimes of Hottentots and baſters (ſee Baster, *Supplement)*, who all differing in colour, reſemble each other in nothing but in villany. They are land pirates, who live without laws and without diſcipline, abandoned to the utmoſt miſery and deſpair; baſe deſerters, who have no other reſources but plundering and crimes. They retire to the ſteepeſt rocks and the moſt inacceſſible caverns, and there they paſs their lives. From theſe elevated places they command an extenſive proſpect over the ſurrounding plains, lie in wait for the unwary traveller and the ſcattered flocks, pour down upon them with the velocity of an arrow, and ſuddenly falling upon the inhabitants and their cattle, ſlaughter them without diſtinction. Loaded with booty, and whatever they can carry with them, they then repair to their gloomy caves, which they never quit till, like the lions, hunger again impels them to freſh maſſacres. But as treachery always marches with a trembling ſtep, and as the preſence of one reſolute perſon is ſufficient to overawe whole troops of theſe banditti, they carefully ſhun thoſe plantations where they are certain that the owners themſelves reſide. Artifice and cunning, the uſual reſources of timid ſouls, are the only means which they employ, and the only guides that accompany them in their expeditions."—*Vaillant's Travels into the Interior Parts of Africa.*

BOSTON, (Encyclopædia.) The following more accurate deſcription is from Dr Morſe's Gazetteer.

Boston, The capital of the ſtate of Maſſachuſetts, the largeſt town in New England, and the third in ſize and rank in the United States, lies in 42. 23. 15. N. lat. and 70. 58. 53. W. long. This town, with the towns of Hingham, Chelſea and Hull, conſtitute the county of Suffolk; 176 miles S. W. of Wiſcaſſet, 61 S. by W. of Portſmouth, 164 N. E. of New-Haven, 252 N. E. of New-York, 347 N. E. of Philadelphia, and 500 N. E. of the city of Waſhington. Boſton

ton is built upon a peninſula of irregular form at the bottom of Maſſachuſetts Bay, and is joined to the main land by an iſthmus on the ſouth end of the town leading to Roxbury. It is two miles long but is of unequal breadth: the broadeſt part is 726 yards. The peninſula contains about 700 acres (other accounts ſay 1000) on which are 2376 dwelling houſes. The number of inhabitants in 1790 was 18,038, but the increaſe has been very conſiderable ſince. The town is interſected by 97 ſtreets, 36 lanes, and 26 alleys, beſides 18 courts, &c. moſt of theſe are irregular, and not very convenient. State-ſtreet, Common-ſtreet, and a few others, are exceptions to this general character; the former is very ſpacious, and being on a line with Long Wharf, where ſtrangers uſually land, exhibits a flattering idea of the town.

Here are nineteen edifices for public worſhip, of which nine are for Congregationaliſts, three for Epiſcopalians, and two for Baptiſts; the Friends, Roman Catholics, Methodiſts, Sandemanians and Univerſaliſts have one each. Moſt of theſe are ornamented with beautiful ſpires, with clocks and bells. The other public buildings are the State-Houſe, Court-Houſe, two Theatres, Concert Hall, Faneuil Hall, Gaol, an Alms-Houſe, a Work-Houſe, a Bridewell and Powder Magazine. Franklin Place, adjoining Federal-ſtreet Theatre, is a great ornament to the town; it contains a monument of Dr. Franklin from whom it takes its name, and is encompaſſed on two ſides with buildings, which, in point of elegance, are not exceeded, perhaps, in the United States. Here are kept in capacious rooms, given and fitted up for the purpoſe, the Boſton Library, and the valuable Collections of the Hiſtorical Society. Moſt of the public buildings are handſome, and ſome of them are elegant. A magnificent State-Houſe is now erecting in Boſton, on the S. ſide of Beacon Hill, fronting the Mall, the corner-ſtone of which was laid with great formality and parade on the 4th of July, 1795; and which over-tops the monument on Beacon Hill.

The Market Place, in which Faneuil Hall is ſituated, is ſupplied with all kinds of proviſions which the country affords. The fiſh market in particular, by the bounteous ſupplies of the ocean and rivers, not only furniſhes the rich with the rareſt productions, but often provides the poor with a cheap and grateful repaſt.

Boſton Harbor, is formed by Point Alderton on the S. and by Nahant Point on the N. The harbor is capacious enough for 500 veſſels to ride at anchor in good depth of water; whilſt the entrance is ſo narrow as ſcarcely to admit two ſhips abreaſt. It is variegated with about forty iſlands, of which fifteen only can be properly called ſo; the others being ſmall rocks or banks of ſand, ſlightly covered with verdure. Theſe iſlands afford excellent paſturage, hay and grain, and furniſh agreeable places of reſort in ſummer to parties of pleaſure. Caſtle Iſland is about three miles from the town; its fortifications, formerly called Caſtle William, defend the entrance of the harbor. It is garriſoned by about fifty ſoldiers, who ſerve as a guard for the convicts, who are ſent here to hard labour. The convicts are chiefly employed in making nails.

The Light-Houſe ſtands on a ſmall iſland on the N. entrance of the channel, (Point Alderton and Nantaſket Heights being on the S.) and is about 65 feet high. To ſteer for it from Cape Cod, the courſe is W. N. W. when within one league of the Cape; from Cape Cod to the Light-Houſe is about 16 leagues; from Cape Ann the courſe is S. W. diſtant 10 leagues. A cannon is lodged and mounted at the Light Houſe to anſwer ſignals.

Only ſeven of the iſlands in the bay are within the juriſdiction of the town, and taxed with it, viz. Noddle's, Hog, Long, Deer, Spectacle, Governor's and Apple Iſlands.

The wharves and quays in Boſton are about eighty in number, and very convenient for veſſels. Long Wharf, or Boſton Pier, in particular, extends from the bottom of State-ſtreet 1743 feet into the harbor in a ſtraight line. The breadth is 104 feet. At the end are 17 feet of water at ebb tide. Adjoining to this wharf on the north is a convenient wharf called Minot's T, from the name of its former proprietor and its form. Veſſels are ſupplied here with freſh water from a well ſurrounded by ſalt water, which has been dug at a great expenſe. Long Wharf is covered on the north ſide with large and commodious ſtores, and in every reſpect exceeds any thing of the kind in the United States. In February, 1796, a company was incorporated to cut a canal between this harbor and Roxbury, which is nearly completed.

The view of the town, as it is approached from the ſea, is truly beautiful and pictureſque. It lies in a circular and pleaſingly irregular form round the harbour, and is ornamented with ſpires, above which the monument of Beacon Hill riſes pre-eminent; on its top is a gilt eagle bearing the arms of the Union, and on the baſe of the column are inſcriptions, commemorating ſome of the moſt remarkable events of the late war. Beacon Hill is the higheſt ground on the peninſula, and affords a moſt delightful and extenſive proſpect. The common below it contains about 45 acres always open to refreſhing breezes; on its eaſt ſide is the Mall, a very pleaſant walk above 500 yards in length, adorned with rows of trees, to which an addition of about 100 yards has been lately added. Charles River and Weſt Boſton bridges are highly uſeful and ornamental to Boſton; and both are on Charles River, which mingles its waters with thoſe of Myſtic River, in Boſton harbor. Charles River bridge connects Boſton with Charleſtown in Middleſex county, and is 1503 feet long, 42 feet broad, ſtands on 75 piers, and coſt the ſubſcribers 50,000 dollars. It was opened June 19, 1787.

	Feet long.
Weſt Boſton bridge ſtands on 180 piers, is	3483
Bridge over the gore, 14 piers,	275
Abutment Boſton ſide,	87½
Cauſeway,	3344
Diſtance from the end of the Cauſeway to Cambridge meeting-houſe,	7810
Width of the Bridge,	40

This beautiful bridge exceeds the other as much in elegance as in length, and coſt the ſubſcribers 76,700 dollars. Both bridges have draws for the admiſſion of veſſels, and lamps for the benefit of evening paſſengers.

Seven Free Schools are ſupported here at the public expenſe, in which the children of every claſs of citizens may freely aſſociate together. The number of ſcholars is computed at about 900, of which 160 are taught Latin, &c. There are beſides theſe many private ſchools.

The principal ſocieties in the Commonwealth hold their meetings in this town, and are, the Marine Society, American Academy of Arts and Sciences, Maſſachuſetts Agricultural Society, Maſſachuſetts Charitable Society, Boſton Epiſcopal Charitable Society, Maſſachuſetts Hiſtorical Society, Society for propagating the Goſpel, Maſſachuſetts Congregational Society, Medical Society, Humane Society, Boſton Library Society, Boſton Mechanic Aſſociation, Society for the aid of Immigrants, Charitable Fire Society, and ſeven reſpectable Lodges of free and accepted Maſons.

The foreign and domeſtic trade of Boſton is very conſiderable, to ſupport which there are three Banks, viz. the Branch of the United States Bank, the Union, and the Maſſachuſetts Bank; the latter conſiſts of 800 ſhares of 500 dollars, equal to 400,000; the capital of the Union Bank is, 1,200,000 dollars, 400,000 of which is the property of the State. In 1748, 500 veſſels cleared out of this port for, and 430 were entered from, foreign parts. In 1784, the entries of foreign and coaſting veſſels were 372, and the clearances 450. In 1794, the entries from foreign ports were 567. In 1795, theſe entries amounted to 725, of which the ſhips were 96, barques 3, ſnows 9, polacre 1, brigs 185, dogger 1, ſchooners 362, ſhallop 1, and ſloops 65. The principal manufactures conſiſt of rum, loaf-ſugar, beer, ſail-cloth, cordage, wool and cotton cards, playing cards, pot and pearl aſhes, paper hangings, hats, plate, glaſs, tobacco, and chocolate. There are thirty diſtilleries, two breweries, eight ſugar houſes, and eleven ropewalks.

Eight years ago, the intercourſe with the country barely required two ſtages and twelve horſes, on the great road between this and New-Haven, diſtant 164 miles; whereas there are now twenty carriages and one hundred horſes employed. The number of the different ſtages that run through the week from this town is upwards of 20, eight years ago there were only three.

Attempts have been made to change the government of the town from its preſent form to that of a city; but this meaſure, not according with the democratic ſpirit of the people, has as yet failed. At an annual meeting in March, nine Selectmen are choſen for the government of the town; at the ſame time are choſen a Town Clerk, a Treaſurer, 12 Overſeers of the Poor, twenty-four Firewards, twelve Clerks of the Market, twelve Scavengers, twelve Conſtables, beſides a number of other officers. If the inhabitants do not reap all the advantages they have a right to expect from their numerous officers, it is not for want of wholeſome laws for the regulation of the weights, meaſures and quality of proviſions, or other branches of police, but, *becauſe the laws are not put in execution.*

Beſides thoſe called Trained Bands, there are four other military companies in Boſton, viz. the Ancient and Honourable Artillery Company, the Cadets, Fuſiliers and Artillery Company. The Ancient and Honourable Artillery Company was incorporated in 1638, and the election of a captain and officers of it for the year is on the firſt Monday in June annually, which is obſerved here as a day of feſtivity. Several officers in the American army, who ſignalized themſelves in the late war, received their firſt knowledge of tactics in this military ſchool.

Boſton was ſettled as early as 1631, from Charleſtown; it was called Shaumut by the Indians; Trimountain by the ſettlers in Charleſtown, from the view of its three hills; and had its preſent name in token of reſpect to the Rev. Mr Cotton, a miniſter of Boſton in England, and afterwards miniſter of the firſt church here. Boſton was greatly damaged by an earthquake in October 29, 1727, and ſince that time has ſuffered ſeverely by numerous fires, the houſes being moſtly built of wood. The laſt large fire happened July 30, 1794, and conſumed 96 houſes, rope-walks, &c. and the account of loſſes given in by the ſufferers amounted to 209,861 dollars.

It was in Boſton that the Revolution originated which gave independence to America, and from thence flew like an electrical ſhock throughout the Union. It ſuffered much at the commencement of the war, by the loſs of an extenſive trade, and other calamities. Boſton feels a pride in having given birth to Benjamin Franklin, and a number of other patriots, who were among the moſt active and influential characters in effecting the revolution.

BOSWELL (James), known to the learned world as the author of a life of Dr Johnſon and of ſeveral other valuable works, was born, we believe, at Auchinleck in Ayrſhire, in 1740. The family from which he ſprung was ancient and honourable. At the time of his birth his father was a well employed lawyer at the Scotch bar; but was afterwards raiſed to the dignity of Judge, and filled that important ſtation with acknowledged learning, probity, and honour. His title was Lord Auchinleck, taken from his family inheritance; and he died in 1782: on which occaſion Dr Johnſon wrote an elegant and inſtructive letter to the ſubject of this brief memorial; of which we ſhall tranſcribe a paſſage that alludes to ſome ſlight domeſtic differences, which did not happen in vain, ſince they gave riſe to ſuch ſalutary advice:

"Your father's death had every circumſtance that could enable you to bear it. It was at a mature age, and it was expected; and as his general life had been pious, his thoughts had, doubtleſs, for many years paſt, been turned upon eternity. That you did not find him ſenſible muſt doubtleſs grieve you: his diſpoſition towards you was undoubtedly that of a kind, though not of a fond father. Kindneſs, at leaſt actual, is in our own power, but fondneſs is not; and if, by negligence or imprudence, you had extinguiſhed his fondneſs, he could not at will rekindle it. Nothing then remained between you but mutual forgiveneſs of each other's faults, and mutual deſire of each other's happineſs."

The occaſion of this family diſſention is unknown to us. It might originate in the difference of their political principles, Mr Boſwell being a zealous Tory, and his father, as he repreſents him, a rancorous Whig; or it may have ariſen from the celebrated Douglas cauſe, which ſet many friends at variance in Scotland, and in which Lord Auchinleck and his ſon took oppoſite ſides. The Judge gave his vote on the bench for the Duke of Hamilton; and the advocate (for Mr Boſwell was then at the bar) was ſo keen a partizan of Douglas, that when the cauſe was finally decided by the Houſe of

Peers, he got poſſeſſion of a Chineſe *gong*, and, at the head of a number of young men and boys patrolled the ſtreets of Edinburgh, and made a loud and exulting noiſe at the windows of his father's houſe, where there was no ſymptom diſplayed of the general joy.

In 1762 Mr Boſwell made his firſt journey to London; where, under the auſpices of Dodſley the bookſeller, he publiſhed, "The Cub at Newmarket, a Tale." By the title of *Cub* he meant to characterize himſelf, as the reader will perceive in the following lines, which we ſhall give as a ſpecimen of the poem:

> Lord Eglintoune, who loves, you know,
> A little daſh of whim, or ſo,
> By chance a curious CUB had got,
> On Scotia's mountains newly caught.

During his ſtay in London, Mr Boſwell was introduced to Dr Johnſon, with whom it is well known he continued to live in intimacy from that time till Johnſon's death in 1784; and this intimacy procured him the friendſhip of Burke, Goldſmith, Sir Joſhua Reynolds, and many other men of eminence, who compoſed what was called *The Literary Club*. In the latter end of 1765 he became acquainted with General Paoli when on his travels; and after his return he publiſhed, in 1768 or 1769, his account of Corſica, with the "Journal of a Tour to that Iſland."

Of this work, which gained him ſome diſtinction in the world, his great friend Johnſon writes thus: "Your hiſtory is like all other hiſtories, but your journal is in a very high degree curious and delightful. There is between the hiſtory and the journal that difference which there will always be found between notions borrowed from without and notions generated within. Your hiſtory was copied from books; your journal roſe out of your own experience and obſervation. You expreſs images which operated ſtrongly upon yourſelf, and you have impreſſed them with great force upon your readers. I know not whether I could name any narrative by which curioſity is better excited or better gratified."

In 1770 Mr Boſwell, who was then in good practice at the Scotch bar, married an amiable woman, by whom he had two ſons and three daughters, who ſurvived him. In 1773 he was choſen a member of the LITERARY CLUB; and in the autumn of the ſame year he viſited the Hebrides in company with his illuſtrious friend Johnſon; after whoſe death he publiſhed a very entertaining account of their tour, the places they ſaw, the characters with whom they converſed, and their own remarks on the different converſations. To many perſons, both in England and Scotland, this book gave great offence, as it brought before the public the unguarded talk of private ſocial circles; but it ſurely furniſhed much entertainment, as it exhibited a more faithful picture of Hebridian manners than the Britiſh public had ever before ſeen.

In 1784, when Mr Fox's famous India bill was before Parliament, Mr Boſwell publiſhed a "Letter to the People of Scotland on the Preſent State of the Nation;" in which he contends, that no charter would be ſafe if that bill ſhould paſs into a law; and more than inſinuates, that the principle of it was equally inimical to the liberties of the ſubject and to the prerogative of the king. Dr Johnſon ſeems to have thought of that bill as he did; for having read the letter, he writes to the author his approbation of it in the following words: "I am very much of your opinion; and, like you, feel great indignation at the indecency with which the king is every day treated. Your paper contains very conſiderable knowledge of the hiſtory and of the conſtitution, very properly produced and applied."

In 1785 Mr Boſwell quitted the Scotch bar, and went to reſide in London, where he continued till the day of his death. Having entered himſelf in one of the inns of court, and ſtudied the Engliſh law, he became a barriſter in England: but we have reaſon to believe that his practice there was not ſo ſucceſsful as it had been in his own country. He enjoyed, however, more completely than he could do in Edinburgh, the converſation of the great, the wiſe, the witty, and the good; and ſuch converſation he always valued above wealth. He frequently viſited his native country, and eſpecially Auchinleck, the ſeat of his anceſtors; and ſoon after his return from one of thoſe viſits he was ſeized with a diſorder which proved fatal, on Tueſday the 19th of May 1795.

Such were the principal events in the life of Mr Boſwell. Of his character, it would be difficult to ſay *much more* than he has ſaid himſelf in his "Journal of a Tour to the Hebrides;" and which may, with ſome propriety, be copied here:

"I have given a ſketch of Dr Johnſon. My readers may wiſh to know a little of his fellow-traveller. Think, then, of a gentleman of ancient blood; the pride of which was his predominant paſſion. He was then in his 33d year, and had been about four years happily married. His inclination was to be a ſoldier; but his father, a reſpectable Judge, had preſſed him into the profeſſion of the law. He had travelled a good deal, and ſeen many varieties of human life. He had thought more than any body ſuppoſed, and had a pretty good ſtock of general learning and knowledge. He had all Dr Johnſon's principles, with ſome degree of relaxation. He had rather too little than too much prudence; and his imagination being lively, he often ſaid things of which the effect was very different from the intention. He reſembled ſometimes

> 'The beſt good man, with the worſt-natur'd muſe.'

"He cannot deny himſelf the vanity of finiſhing with the encomium of Dr Johnſon, whoſe friendly partiality to the companion of this tour repreſents him as one 'whoſe acuteneſs would help my inquiry, and whoſe gaiety of converſation, and civility of manners, are ſufficient to counteract the inconveniences of travel, in countries leſs hoſpitable than we have paſſed."

Few of Mr Boſwell's friends, we believe, could add much to this candid confeſſion. His enemies, if he had any, might dwell upon his failings; but his failings were few, and injurious to no perſon. In his character good nature was predominant. He appeared to entertain ſentiments of benevolence to all mankind, and to be incapable of *intentionally* injuring a human being. His converſation-talents were always pleaſing, and often faſcinating. But can we wonder at this in him who, with a capacity to learn, had been the companion of Johnſon for more than 20 years? His attachment to the Doctor for ſo long a period was a meritorious perſeverance in the deſire of knowledge. To it the world is indebted for the moſt finiſhed picture of an eminent man that ever was executed. We know there are objections to the *mode* of giving the life of Johnſon. It has been thought that ignorance has been wantonly expoſed, and the privacy of ſocial life endangered. We ſhall not enter deeply into this queſtion. All that we can certainly affirm is, that the work has been read with avidity and pleaſure; and that he who does not wiſh to read it again may be ſuſpected to be deficient in taſte and in temper.

Mr Boſwell has been accuſed of vanity; but when this accuſation is brought againſt him, it ſhould not be forgotten that he enjoyed advantages which rendered that conſpicuous in him from which no man can claim an exemption. We know not the man who would not have been vain to poſſeſs ſo much of Dr Johnſon's converſation, and proud to give it to the world, in hopes that he who venerated Johnſon would not be unthankful to his biographer. From the Doctor, however, he appeared to his friends to have imbibed a portion of melancholy, of which indeed he complained himſelf during the laſt two or three years of his life; and he flew for relief where perhaps it is beſt to be found, to the ſociety of the learned and the gay. Here, as he confeſſes, he had rather *too little* than too much *prudence;*" and, with more attachment to the activity of rural life, he might, probably, have lengthened his days. But as his "belief in revelation was unſhaken," and his religious impreſſions deep, and recurring frequently, let us hope that he has now attained that ſtate from which imperfection and calamity are alike excluded.

BOTANY-BAY, See *New Holland*, Encycl.; and *New South Wales* in this Supplement.

BOTETOURT, a county in Virginia, on the Blue Ridge, W. of which are the Sweet Springs, about 42 miles from the Warm Springs. Its chief town is Fincaſtle.—*Morſe.*

BOUDOIR, LE, a ſmall iſland in the Pacific Ocean, S. lat. 17. 52. W. long. from Paris, 15. 25.; diſcovered April 2, 1768, by Bouganville. This iſland, the year before, had been diſcovered by Wallis, and named *Oſnaburg*.—The natives call it *Maitea*, according to the report of Capt. Cook, who viſited it in 1769. Quiros diſcovered this iſland in 1606, and called it *la Dezana*.—*ib.*

BOUGUER (Peter), an eminent mathematician and mechanical philoſopher, was born at Croiſic, in Lower Bretagne, on the 10th of February 1698. His father John Bouguer, who was likewiſe a conſiderable mathematician, was then profeſſor royal of hydrography at that port; and under him young Bouguer ſtudied mathematics, and the application of them to ſhip-building, almoſt from the period when he began to ſpeak; ſo that he was a proficient in theſe ſciences before he had reached beyond the years of childhood. He was, however, removed from Croiſic to the Jeſuits college at Vannes, where at 13 years of age, he triumphed, in a public conteſt, over a profeſſor of mathematics, who had advanced a mathematical propoſition erroneouſly. Two years after this he loſt his father, whom he was appointed to ſucceed in the office of hydrographer, after being publicly examined, and giving the moſt complete proof of his being duly qualified to fill the vacant chair. He was indeed qualified by prudence as well as by ſcience; for however ſurpriſing it may be, he filled it both with dignity and with abilities, though then not more than 15 years of age.

In the years 1727, 1729, and 1731, he gained the prizes ſucceſſively propoſed by the Academy of Sciences for eſſays on the beſt way of equipping ſhips with maſts, on the beſt method of obſerving at ſea the height of the ſtars, and on the moſt advantageous way of obſerving the declination of the magnetic needle or the variation of the compaſs. In 1729 he publiſhed an *Optical Eſſay upon the Gradation of Light*, in which he examined the intenſity of light, and determined its degrees of diminution in paſſing through different pellucid mediums, and particularly in traverſing the earth's atmoſphere. Of this eſſay, which was written upon a ſubject that till then had not attracted the attention of philoſophers, the reader will find ſome account in the *Encyclopædia*, under the title Optics, n° 32, &c.

In 1730 Bouguer was removed from the port of Croiſic to that of Havre. In 1731 he obtained, in the Academy of Sciences, the place of aſſociate geometrician, vacant by the promotion of Maupertuis to that of penſioner; and in 1735 he was promoted to the office of penſioner aſtronomer. The ſame year he was ſent on the commiſſion to South America, along with Meſſrs Godin, Condamine and Jeuſſieu, to determine the meaſure of the degrees of the meridian, and the figure of the earth. In this painful and troubleſome buſineſs of ten years duration, chiefly among the lofty Cordelier mountains, our author, beſides attending to the object of the voyage, made many ſcientific obſervations, viz. on the effect of the Cordeliers on the polarity of the magnetic needle; on the expanſion and contraction of metals and other ſubſtances, by the ſudden and alternate changes of heat and cold among thoſe mountains; and on the refraction of the atmoſphere from the tops of the ſame, with the ſingular phenomenon of the ſudden increaſe of the refraction, when the ſtar can be obſerved below the line of the level. He likewiſe aſcertained the laws of the denſity of the air at different heights, from obſervations made at different points of thoſe enormous mountains; he diſcovered that the mountains have an effect upon a plummet, though he did not aſſign the quantity of that effect; he found out a method of eſtimating the errors committed by navigators in determining their route; gave a new conſtruction of the log for meaſuring a ſhip's way; and made ſeveral other uſeful improvements. M. Bouguer made at different times ſome important experiments on the famous reciprocation of the pendulum; he invented in 1747 the heliometer (ſee that article *Encycl.)*; and made many diſcoveries relating to the intenſity of light (for which ſee Optics-*Index*, Encycl.) His unremitting application to ſtudy undermined his health, and he died on the 15th of Auguſt 1758, in the 61ſt year of his age.

Of his works which have been publiſhed, the chief are, 1. The Figure of the Earth, determined by the Obſervations made in South America, 1749, in 4to. 2. Treatiſe on Navigation and Pilotage, Paris, 1752, in 4to. This work has been abridged by M. La Caille, in one volume 8vo, 1768. 3. Treatiſe on Ships, their Conſtruction and Motions, in 4to, 1756. 4. Optical Treatiſe on the Gradation of Light, firſt in 1729, then a new edition in 1760, in 4to.

His papers that were inſerted in the Memoirs of the

Academy are very numerous and important: as in the Memoirs for 1726, compariſon of the force of the ſolar and lunar light with that of candles; 1731, obſervations on the curvilinear motion of bodies in mediums; 1732, upon the new curves called the *lines of purſuit;* 1733, to determine the ſpecies of conoid, to be conſtructed upon a given baſe which is expoſed to the ſhock of a fluid, ſo that the impulſe may be the leaſt poſſible; determination of the orbit of comets; 1734, compariſon of the two laws which the earth and the other planets muſt obſerve in the figure which gravity cauſes them to take; on the curve lines proper to form the arches in domes; 1735, obſervations on the equinoxes; on the length of the pendulum; 1736, on the length of the pendulum in the torrid zone; on the manner of determining the figure of the earth by the meaſure of the degrees of latitude and longitude; 1739, on the aſtronomical refractions in the torrid zone; obſervations on the lunar eclipſe of the 8th September 1737, made at Quito; 1744, ſhort account of the voyage to Peru by the members of the Royal Academy of Sciences, to meaſure the degrees of the meridian near the equator, and from thence to determine the figure of the earth; 1745, experiments made at Quito and divers other places in the torrid zone, on the expanſion and contraction of metals by heat and cold; on the problem of the maſting of ſhips; 1746, treatiſe on ſhips, their ſtructure and motions; on the impulſe of fluids upon the fore parts of pyramidoids, having their baſe a trapezium; continuation of the ſhort account given in 1744 of the voyage to Peru for meaſuring the earth; 1747, on a new conſtruction of the log, and other inſtruments for meaſuring the run of a ſhip; 1748, of the diameters of the larger planets; the new inſtrument called a *heliometer,* proper for determining them, with obſervations of the ſun; obſervation of the eclipſe of the moon the 8th of Auguſt 1748; 1749, ſecond memoir on aſtronomical refractions, obſerved in the torrid zone, with remarks on the manner of conſtructing the tables of them; figure of the earth determined by MM. Bouguer and Condamine, with an abridgement of the expedition to Peru; 1750, obſervation of the lunar eclipſe of the 13th December 1750; 1751, on the form of bodies moſt proper to turn about themſelves, when they are puſhed by one of their extremities, or any other point; on the moon's parallax, with the eſtimation of the changes cauſed in the parallaxes by the figure of the earth; obſervation of the lunar eclipſe the 2d of December 1751; 1752, on the operations made by ſeamen called *corrections;* 1753, obſervation of the paſſage of Mercury over the ſun the 6th of May 1753; on the dilatations of the air in the atmoſphere; new treatiſe of navigation, containing the theory and practice of pilotage, or working of ſhips; 1754, operations, &c. for diſtinguiſhing, among the different determinations of the degree of the meridian near Paris, that which ought to be preferred; on the direction which the ſtring of a plummet takes; ſolution of the chief problems in the working of ſhips; 1755, on the apparent magnitude of objects; ſecond memoir on the chief problems in the working of ſhips; 1757, account of the treatiſe on the working of ſhips; on the means of meaſuring the light.

BOURBON *Co.* in Kentucky, between Licking and Kentucky rivers, contains 7837 inhabitants, including 908 ſlaves.—*Morſe.*

BOURBON, a poſt town and capital of the above county, ſtands on a point of land formed by two of the ſouthern branches of Licking River; 22 miles N. E. of Lexington, 21 eaſterly of Lebanon, and 749 W. S. W. from Philadelphia, and contains about 60 houſes, a Baptiſt church, a court-houſe and goal. There are ſeveral valuable mills in its vicinity.—*ib.*

BOW, is a townſhip in Rockingham co. New-Hampſhire, on the W. bank of Merrimack River, a little S. of Concord. It contains 568 inhabitants. —*ib.*

BOWDOIN, a townſhip in Lincoln co. Diſtrict of Maine, on the N. eaſtern bank of Androſcoggin River; diſtant from York, N. eaſterly, 36 miles, and from the mouth of Kennebeck River 6 miles, and 166 N. E. of Boſton. It contains 983 inhabitants.—*ib.*

BOWDOINHAM, a townſhip in Lincoln co. diſtrict of Maine, ſeparated from Pownalborough E. and Woolwich S. E. by Kennebeck River. It has 455 inhabitants, and lies 171 miles N. E. from Boſton.—*ib.*

BOWLING *Green,* a village in Virginia, on the poſt road, 22 miles S. of Fredericksburg, 48 N. of Richmond, and 25 N. of Hanover court-houſe.—*ib.*

BOXFORD, a ſmall townſhip in Eſſex co. Maſſachuſetts, having 925 inhabitants. It lies on the S. E. ſide of Merrimack River, 7 miles weſterly of Newburyport. In the ſouthernmoſt of its two pariſhes is a bloomery.—*ib.*

BOYLSTON, a townſhip in Worceſter co. Maſſachuſetts, having 839 inhabitants; 10 miles N. E. of Worceſter, and 45 N. W. of Boſton. It was incorporated in 1786, having been a pariſh of Shrewſbury ſince 1742; and contains by ſurvey, 14,396 acres of land, well watered, and of a rich ſoil.—*ib.*

BRADDOCK's *Field,* the place where Gen. Braddock, with the firſt diviſion of his army, conſiſting of 1400 men, fell into an ambuſcade of 400 men, chiefly Indians, by whom he was defeated and mortally wounded, July 9, 1755. The American militia, who were diſdainfully turned in the rear, continued unbroken and ſerved as a rear guard, and, under Col. Waſhington, the late Preſident of the U. S. A. preſerved the regulars from being entirely cut off. It is ſituated on Turtle Creek, on the N. E. bank of Monongahela River, 6 miles E. S. E. from Pittſburg.—*ib.*

BRADDOCK's *Bay,* on the S. ſide of Lake Ontario, 42 miles W. from Great Sodus, and 65 E. from Fort Niagara.—*ib.*

BRADFORD, *Eaſt* and *Weſt,* are townſhips in Cheſter co. Pennſylvania.—*ib.*

BRADFORD, a townſhip in Eſſex co. Maſſachuſetts, ſituated on the S. ſide of Merrimack River, oppoſite Haverhill, and 10 miles W. of Newburyport. It has two pariſhes, and 1371 inhabitants. Quantities of leather ſhoes are made here for exportation; and in the lower pariſh ſome veſſels are built. Several ſtreams fall into the Merrimack from this town, which ſupport a number of mills of various kinds.—*ib.*

BRADFORD, a townſhip in Hillſborough co. New-Hampſhire, containing 217 inhabitants, incorporated in 1760; 20 miles E. of Charleſtown.—*ib.*

BRADFORD, a townſhip in Orange co. Vermont, on the W. bank of Connecticut River, about 20 miles above Dartmouth College, having 654 inhabitants. There is a remarkable ledge of rocks in this townſhip, as much as 200 feet high. It appears to hang over, and threaten the traveller as he paſſes. The ſpace between this ledge and Connecticut River is ſcarcely wide enough for a road.—*ib.*

BRAINTREE, a townſhip in Orange co. Vermont, lies 75 miles N. eaſtward of Bennington. It joins Kingſton weſtward, Randolph on the eaſtward, and contains 221 inhabitants.—*ib.*

BRAINTREE, one of the moſt ancient townſhips in Norfolk co. in the ſtate of Maſſachuſetts, was ſettled in 1625, and then called *Mount Woolaſton,* from the name of its founder. It lies on a bay, 8 miles E. of S. from Boſton, and contained, before its diviſion, 400 houſes and 2771 inhabitants. Great quantities of granite ſtones are ſent to Boſton from this town for ſale. The bay abounds with fiſh and ſea fowl, and particularly *brants.* This town is noted for having produced, in former and latter times, the firſt characters both in church and ſtate; and, in diſtant ages, will derive no ſmall degree of fame, for having given birth to JOHN ADAMS, the firſt Vice-Preſident, and the ſecond Preſident of the *United States of America;* a man highly diſtinguiſhed for his patriotiſm, as a citizen; his juſtice, integrity, and talents, as a lawyer; his profound and extenſive erudition, as a writer; and his diſcernment, firmneſs, and ſucceſs, as a foreign miniſter and ſtateſman.—*ib.*

BRANDON, a harbor on the N. ſide of Long Iſland, New-York, 9 miles W. of Smithtown, and the ſame diſtance from Hampſtead Plain.—*ib.*

BRANDON, a townſhip in Rutland co. Vermont, ſituated on both ſides of Otter Creek, containing 637 inhabitants, and is about 60 miles northerly from Bennington. Here Brandon Creek empties into Otter Creek from the N. E.—*ib.*

BRANDYWINE *Creek,* falls into Chriſtiana Creek from the northward, at Wilmington, in Delaware ſtate, about 25 miles from its N. and N. weſtern ſources, which both riſe in Cheſter co. Pennſylvania. This Creek is famous for a bloody battle, fought Sept. 11, 1777, between the Britiſh and Americans, which laſted nearly the whole day, and the latter were defeated with conſiderable loſs: but it was far from being of that deciſive kind which people had been led to expect, in the event of a meeting between the hoſtile armies, on nearly equal terms, both as to numbers, and the nature of the ground on which each army was ſituated. It was fought at Chadds Ford, and in the neighbourhood of, and on, the ſtrong grounds at Birmingham church.—*ib.*

BRANDYWINE, a townſhip in Cheſter co. Pennſylvania.—*ib.*

BRANDFORD, a townſhip in New-Haven co. Connecticut, conſiderable for its iron works. It lies on the S. ſide of a river of the ſame name, which runs into Long Iſland ſound, 10 miles E. from New-Haven, and 40 S. of Hartford.—*ib.*

BREAD is ſo eſſential an article of food that every uſeful method of making it ſhould be generally known. Much has accordingly been ſaid on that ſubject (*Encycl.*) under the titles BAKING, BARM, BREAD, and YEAST; but, ſince the laſt of theſe articles was publiſhed, we have ſeen, in Dr Townſon's *Travels in Hungary,* a method of making bread at Debretzen; of which, as it may ſometimes be adopted with advantage in this country, an account may, with propriety, be inſerted here.

In the baking of this bread, a ſubſtitute is uſed for yeaſt, which is thus made: Two good handfuls of hops are boiled in four quarts of water: this is poured upon as much wheaten bran as can be well moiſtened by it: to this are added four or five pounds of leaven; when this is only warm, the maſs is well worked together to mix the different parts. This maſs is then put in a warm place for 24 hours; and after that it is divided into ſmall pieces, about the ſize of a hen's egg, or a ſmall orange, which are dried by being placed upon a board, and expoſed to a dry air, but not to the ſun; when dry, they are laid by for uſe, and may be kept a half year. This is the ferment; and it may be uſed in the following manner: For a baking of ſix large loaves, ſix good handfuls of theſe balls, broken into fragments, are taken and diſſolved in ſeven or eight quarts of warm water. This is poured through a ſieve into one end of the bread-trough, and three quarts more of warm water are poured through the ſieve after it, and what remains in the ſieve is well preſſed out. This liquor is mixed up with ſo much flour as to form a maſs of the ſize of a large loaf: this is ſtrewed over with flour; the ſieve, with its contents, is put upon it, and then the whole is covered up warm, and left till it has riſen enough, and its ſurface has begun to crack: this forms the leaven. Then 15 quarts of warm water, in which ſix handfuls of ſalt have been diſſolved, are poured through the ſieve upon it, and the neceſſary quantity of flour is added, and mixed and kneaded with the leaven: this is covered up warm, and left for about an hour. It is then formed into loaves, which are kept in a warm room half an hour; and after that they are put in the oven, where they remain two or three hours, according to the ſize. The great advantage of this ferment is, that it may be made in great quantities at a time, and kept for uſe. Might it not on this account be uſeful on board of ſhips, and likewiſe for armies when in the field?

Bread, in whatever way it is made, is a dear article, and it may be a deſirable object to many of our readers to know at what price the baker can afford to ſell it. This depends upon the price of wheat, the quantity of flour which the wheat may give, the loſs at the mill, the expence of grinding, and the expence of baking.

Of the price of wheat we can ſay nothing with preciſion, becauſe it varies according to the goodneſs or badneſs of the crop, and other circumſtances; but a buſhel of Eſſex wheat, Wincheſter meaſure, may be taken, on an average, as weighing 60 lb. Sixty pounds of wheat will yield, excluſive of the loſs in grinding and dreſſing, 45½ lb. of that kind of flour which is called *ſeconds;* which alone is uſed, through the greateſt part of England, for bread, and which makes, indeed, the beſt of all bread, though not the whiteſt. A peck of this flour, weighing 14 lb. will take up between ſix and ſeven pints of water, and give 18 lb. of excellent bread; or a buſhel of flour, weighing 56 lb. will yield 72 lb. of bread. The expence of baking a buſhel of ſuch flour is, in Eſſex and ſome other Engliſh counties, about ninepence; viz. yeaſt, on an average, twopence; ſalt, before the late tax, one halfpenny; and baking, ſixpence.

But *ſeconds* is not all that is got from wheat. A buſhel of 60 lb. of wheat gives, beſides 45½ lb. of ſeconds, 13 lb. of offal, i. e. of *pollards* and *bran;* for the utmoſt loſs in grinding and dreſſing a buſhel of wheat ſhould not exceed 1 pound 8 ounces. The millers, indeed, uſually reckon on two pounds of loſs; but we can ſay, with the utmoſt confidence, that the actual loſs is rather leſs than we have ſtated it. A correſpondent of ours, on whoſe accuracy we can depend, weighed, in 1795, two buſhels, Wincheſter meaſure, the one of white and the other of red wheat, and found the weight of them both to be 122 lb. This wheat was ground by his own ſervants, and it yielded 121½ pounds of meal, ſo that there was here but ½ lb. loſt of two buſhels, or of 122 lb. in grinding. He admits that he ſuffered the ſtones to turn too cloſe, and that the loſs ſhould therefore have been ſomewhat greater. The meal was dreſſed, as the wheat had been ground, under his own eye; and every poſſible precaution being taken to prevent his being deceived in the reſult, he had of flour, or *ſeconds*, 93½ lb. and of bran and pollard 25½ lb. ſo that he loſt, of two buſhels, but 2½ lb. both in grinding and dreſſing. The offal, or bran and pollard, being dreſſed in a bolting mill, yielded as follows:

Sharps -	6 lb.	0 oz.
Fine pollard	5	8
Coarſe pollard	7	8
Broad bran	5	8
Altogether	24	8

There was loſt, therefore, in bolting, only one pound; and of the ſharps, about three pounds, if ſifted, would have been good flour. Indeed were the ſharps and fine pollard to be added to the flour, the bread would, perhaps, be better, and more wholeſome, than without ſuch addition. From theſe data, which we believe to be very accurate, it will be eaſy to calculate, if the price of wheat be given, what ſhould be the price of flour per buſhel and peck, the price of bread per pound, and the quantity of bread that ſhould be ſold for a ſhilling.

It is a fact, however, which ſhould be attended to, that loaves are not always of the ſame weight, though made of equal quantities of the very ſame dough. This was fully aſcertained ſome years ago at Paris. On a violent complaint that the bread was not always of the ſame ſtandard weight, the bakers of the city were called before the police officers. They admitted the fact, that loaves, baked at the ſame time, and in the ſame oven, were ſeldom, if ever, of the ſame weight; but they inſiſted, that they contained, each, the ſtandard quantity of dough, and that the variety of weight among them muſt proceed from ſome cauſe, which they did not pretend to aſcertain. The matter was referred to the Royal Academy of Sciences, which appointed one of its members to ſuperintend, for ſome days, the whole proceſs of baking. This being done it was found, that, of loaves baked in a large oven, thoſe were always heavieſt which occupied the centre of the oven, and that the bakers were innocent of the crime with which they were charged. The fact, we think, may eaſily be accounted for. Even in an oven there muſt be ſome condenſation of ſteam; and, from the very ſhape of the oven, the greateſt quantity muſt be condenſed towards the centre. Hence the loaves in the centre are neceſſarily wetter and heavier than thoſe round the circumference, if the plain of the oven has been equally heated.

BREAD of Rice might occaſionally be of great uſe in many countries during a ſcarcity of wheat; but the method of making it is not generally known. It is indeed impoſſible to make bread of the flour of rice, which is harſh and dry like ſand or aſhes, by treating it in the manner in which wheat-flour is commonly treated; and therefore it has been propoſed to mix it with an equal quantity of the flour of rye. But this method of uſing the flour of rice is a very uncertain remedy in caſe of want; ſince we can have no rice-bread if we have not rye. We are taught, however, in the *Journal des Sciences, des Lettres, et des Arts,* how to make excellent bread from rice alone, by a method which the author of the memoir ſays he learned from the natives of America.

According to this method of making the wiſhed-for bread, the firſt thing to be done to the rice is, to reduce it to flour, by grinding it in a mill, or, if we have not a mill, it may be done in the following manner: Let a certain quantity of water be heated in a ſaucepan or caldron; when the water is near boiling, let the rice we mean to reduce into flour be thrown into it: the veſſel is then to be taken off the fire, and the rice left to ſoak till the next morning. It will then be found at the bottom of the water, which is to be poured off, and the rice put to drain upon a table placed in an inclined poſition. When it is dry, it muſt be beat to powder, and paſſed through the fineſt ſieve that can be procured.

When we have brought the rice into flour, we muſt take as much of it as may be thought neceſſary, and put it into the kneading-trough in which bread is generally made. At the ſame time we muſt heat ſome water in a ſaucepan or other veſſel, and, having thrown into it ſome handfuls of rice, we muſt let them boil together for ſome time: the quantity of rice muſt be ſuch as to render the water very thick and glutinous. When this glutinous matter is a little cooled, it muſt be poured upon the rice-flour, and the whole muſt be well kneaded together, adding thereto a little ſalt, and a proper quantity of leaven. We are then to cover the dough with warm cloths, and to let it ſtand that it may riſe. During the fermentation, this paſte (which, when kneaded, muſt have ſuch a proportion of flour as to render it pretty firm) becomes ſo ſoft and liquid that it ſeems impoſſible it ſhould be formed into bread. It is now to be treated as follows:

While the dough is riſing, the oven muſt be heated: and, when it is of a proper degree of heat, we muſt take a ſtewpan of tin, or copper tinned, to which is fixed a handle of ſufficient length to reach to the end of the oven. A little water muſt be put into this ſtewpan, which muſt then be filled with the fermented paſte, and covered with cabbage or any other large leaves, or with a ſheet of paper. When this is done, the ſtewpan is to be put into the oven, and puſhed forward to the part where it is intended the bread ſhall be baked; it muſt then be quickly turned upſide down. The heat of the oven acts upon the paſte in ſuch a way as to prevent its ſpreading, and keeps it in the form the ſtewpan has given it.

In this manner pure rice-bread may be made; it comes out of the oven of a fine yellow colour, like paſtry which has yolk of eggs over it. It is as agreeable to the taſte as to the ſight; and may be made uſe of, like wheat-bread, to put into broth, &c. It muſt, however, be obſerved, that it loſes its goodneſs very much as it becomes ſtale.

It may be here remarked, that the manner in which Indian corn is uſed in ſome countries, for making bread, can only produce (and does in fact produce) very bad dough, and of courſe very bad bread. To employ it advantageouſly, it ſhould be treated like rice; and it may then be uſed, not only for making bread, but alſo for paſtry.

BREAKNECK *Hill*, oppoſite Butterhill, at the northern entrance of the highlands, in Hudſon River, about 60 miles N. of New-York. On the S. ſide of this hill, about half the diſtance as you aſcend it, the rocks are ſo ſituated as to give the ſpectator a tolerable idea of a human face, with a noſe, mouth and double chin; but without a forehead. On the noſe grows a tree of conſiderable ſize, which has the appearance only of a ſhrub.—*Morse*.

BREWING is an art of vaſt importance, and has accordingly been explained in the Encyclopædia. A few improvements, however, have been made in the art, which, though not noticed in that Work, ſeem to be worthy of general attention, and, therefore, to deſerve a place in this Supplement. The firſt, of which we ſhall give an account, is an invention of Mr William Ker of *Kerfield*, in the county of Tweedale, for the ſaving of hops, and, at the ſame time, giving to the liquor, whether ale, beer, or porter, a ſuperior flavour and quality.

The ſteam which ariſes from the boiling copper is known to be ſtrongly impregnated with the eſſential oil of the hops, in which their flavour conſiſts. Inſtead, therefore, of allowing it to eſcape and evaporate, as it does in the common mode of brewing, Mr Ker contrives to preſerve and condenſe it, by means of a winding-pipe fixed to the copper, ſimilar to the worm of a ſtill, or by a ſtraight pipe paſſing through cold water, or any other cooling medium. The oil and water, thus obtained, are returned into the worts when boiled, or the oil, after being ſeparated from the water, along with which it had been exhaled, is returned into the worts after they are boiled; and the watery part, which, after the oil is ſeparated, ſtill continues impregnated with the aromatic taſte and bitter of the hop, is returned into the next copper or boiling-veſſel; and ſo on from one copper or boiling-veſſel into another. By this proceſs a conſiderable part of the hop and flavour, which is loſt in the ordinary mode of brewing, is preſerved: the flavour of the liquor is improved by the preſervation of the finer parts of the aromatic oil: and the ale and beer are better ſecured from any tendency to acidity or putrefaction, and therefore muſt be fitter for home conſumption and exportation. For this invention, which is certainly ſimple, and we think rational, Mr Ker obtained a patent dated March 4. 1788.

On the 4th of June 1790, Mr John Long of *Longville*, in the county of *Dublin*, Ireland, obtained a patent for an improvement in brewing, reſembling in one particular, this invention of Mr Ker's. To his invention, however, he gives the name of *an entire new method, in all the eſſential parts*, of brewing good malt-liquor; and therefore, as it comprehends the whole proceſs of brewing, we ſhall lay it before our readers in the words of its author.

“ 1. For the better extracting from malt, place near a maſh-tun a ſhallow copper or other veſſel that will readily heat; the curb of which to be on a level with the tun, and to contain from two to ſix hogſheads, according to the dimenſion of the tun, more or leſs; and, at the lower end of the copper, have a cock from two to five inches diameter, more or leſs, to conduct the heated liquor from the copper into a tube which paſſes down the external part of the tun, and enters it through an aperture about ſix inches from the bottom; then forming two revolutions, more or leſs, through the body of the tun, and communicating its heat to the wort as it paſſes through the tube; and then, at a convenient diſtance from the place it firſt entered, it runs from the tun into a ciſtern or tub, ſituate as near as convenient to the copper or heating-veſſel. In the tub or ciſtern is to be placed a pump, for the purpoſe of conveying the cooler liquor back to the copper or heating-veſſel again; there to receive the heat of 208 degrees, more or leſs (which it will require after the firſt half-hour), and then convey it through the maſhing-tun as before, and in the ſame manner, as long as the working brewer or diſtiller may think neceſſary, to raiſe the maſhing-tun to any degree of heat required. By adhering to the foregoing proceſs, the firſt liquor may, with the greateſt ſafety, be let upon the malt from 20 to 30 degrees lower than the preſent practice; by which means it operates with gentleneſs, opens and expands the malt and raw corn, and prepares it for the reception of ſharper or warmer liquor, ſo as to extract the whole of the ſaccharine quality from the malt and raw corn. By the foregoing method, the maſhing-tun, inſtead of loſing its firſt heat (which it does by the preſent practice), continues to increaſe in heat every moment, by conveying the heated liquor through the tube into the tun; by which means, at the end of two hours, the working brewer or diſtiller can have the tun brought to any degree of heat he ſhall think beſt ſuited to the different qualities of the malt or raw corn. Perſons who would wiſh to ſave expence, may heat their maſhing-tun at the ſide or bottom by a large piece of metallic ſubſtance made fire proof, and fixed therein; which, in ſome degree, will anſwer the end propoſed, but with great trouble and delay.

“ 2. To prevent the wort from receiving a diſagreeable flavour while in the under-back, a tube muſt be placed at the cock of the maſhing-tun, to receive the wort as it comes off, and convey it to a great ciſtern or refrigeratory, which is ſupplied with a ſtream of water. The wort, paſſing through that medium in a ſpiral tube, ſoon loſes that heat which ſo often proves prejudicial to the brewer and diſtiller in warm weather: then paſs it from the tube into a veſſel in which pumps are placed, to return the worts into the copper for the purpoſe of boiling off. All veſſels for receiving the cold wort muſt be placed lower than the ſource whence the wort comes.

“ 3. As the great object of long boiling the wort is remedied, by my invention of taking the extract from the hops in a ſeparate manner from the worts, I boil my worts no longer than from 15 to 20 minutes; and, by purſuing that method, I ſave much time and fuel, and regulate my lengths accordingly.

"4. I ſteep my hops, the preceding day to which they are to be uſed, in a copper or other veſſel, with as much fluid, blood-warm, as will cover the hops, where it is to remain over a ſlow fire at leaſt 14 hours, cloſe covered; the copper at the tenth hour not to be of a greater heat than 175 degrees, continuing ſlow until the laſt hour. Then I bring the copper gradually to a ſimmer or ſlow boil; in which ſtate I let it remain about 10 minutes, and then run off the fluid; and this I do at the ſame time the firſt wort is boiled off, that they may both paſs together through the refrigeratory into the fermentation or working-tun. After the foregoing operation, I cover the hops again with other liquor, and bring the copper to boil as ſoon as convenient, and let it remain in that ſtate a conſiderable time, until the ſecond worts are boiled off. Then I paſs the hop-fluid with the wort, the ſame as in the firſt inſtance; and, if there is a third wort, I boil my hops a third time with ſmall worts and paſs it off as before; by which means I gradually obtain the whole of the eſſential oil and pleaſing bitter from the hops, which is effectually preſerved in the beer.

"5. To cool worts. When the wort is boiled off, it is conducted from the cock of the copper or boiler into a tube of a proper dimenſion, which paſſes the wort from the cock to the large ciſtern or refrigeratory, and there performs ſeveral revolutions, in a ſpiral manner, through the ſame tube; which is immerſed in conſtant ſupply of cold water, where it loſes the greateſt part of its heat in a ſhort time, and thence continues a ſtraight courſe through the tube, a little elevated and of a ſuitable length, placed in brick work, until it meets a ſmall refrigeratory, ſupplied with colder water from a reſervoir made for that purpoſe at the head of the works; whence a continual ſtream runs on the ſurface of the tube down to the great refrigeratory, cooling the wort as it paſſes, in order to enable the working brewer or diſtiller to ſend it into the backs or working-tuns at whatever degree of heat he ſhall think proper. There is no other difference between brewer and diſtiller in this proceſs, but that the diſtiller immediately paſſes the ſtrong wort from the maſhing-tun to the back, through the ſame machinery above inſerted, and the tubes may be made of lead, or any other metallic ſubſtance.

"6. To enable me to brew in the warm ſummer months, I ſink my backs or working tuns at leaſt to a level with the ground, but if deeper the better, and cover them cloſely by an arch made of bricks, or other materials, that will totally exclude the atmoſpheric air from them. I place them as near as poſſible to a ſpring or ſand-drain, as their depth will naturally draw the water thence, which muſt be ſo contrived as to paſs or flow round the backs or tuns. I then introduce a large tube, which paſſes through the tuns, and keeps the wort ſeveral degrees lower than can poſſibly be done by the preſent practice; by which means I can produce a complete fermentation even in the dog-days.

"7. In cold or froſty weather, if the tun and backs ſhould loſe the firſt heat, intended to carry it through the proceſs by the foregoing method, you may convey a ſupply of warm or boiling water by the tube, which paſſes through the body of the backs or tun, communicating its heat. which riſes to any degree the working brewer ſhall think proper: by purſuing this method, in the coldeſt ſeaſon, I never want a fermentation."

We regret that we cannot with propriety ſtate to our readers, under this article, a ſummary of Mr Richardſon of Hull's *Philoſophical Principles of Brewing;* for as the author has a new edition of his work in the preſs, it is our duty rather to refer to it, than to quote from a former edition, which contains not his laſt improvements. See FERMENTATION and MALT, in this Supplement.

BRIAR *Creek*, a water of Savannah River, in Georgia. Its mouth is about 50 miles S. E. by S. from Auguſta, and 55 N. weſterly from Savannah. Here Gen. Prevoſt defeated a party of 2000 Americans, under Gen. Aſh, May 3, 1779; they had above 300 killed and taken, beſides a great number drowned in the river and ſwamps. The whole artillery, baggage and ſtores were taken.—*Morſe.*

BRIDEALE. See SCOTALE in this Supplement.

BRIDGE. See that article *(Encycl.)*, and ARCH in this Supplement. A *wooden*-bridge, of large ſpan, ſhould be conſtructed on the principles explained under the title ROOF *(Encycl.)* See alſo CENTRE *(Suppl.)*

BRIDGETOWN, in Cumberland co. diſtrict of Maine, having Hebron on the N. W. and Bakerſtown (on the W. ſide of Androſcoggin River,) on the S. E. which three ſettlements lie on the northern ſide of Little Androſcoggin River. It contains 329 inhabitants and lies 34 miles N. by N. W. from Portland; and 156 N. E. from Boſton. Bridgetown conſiſts of large hills and vallies: the highland affords red oak, which are often three feet and ſometimes four, in diameter; and 60 or 70 feet without any branches. The vallies are covered with rock maple, baſs, aſh, birch, pine, and hemlock. There is a curioſity to be ſeen in Long Pond, which lies moſtly in Bridgetown, which may afford matter of ſpeculation to the natural philoſopher.

On the eaſterly ſide of the pond is a cove which extends about 100 rods farther E. than the general courſe of the ſhore, the bottom is clay, and ſo ſhoal that a man may wade 50 rods into the pond. On the bottom of this cove are ſtones of various ſizes, which, it is evident from various circumſtances, have an annual motion towards the ſhore; the proof of this is the mark or track left behind them, and the bodies of clay driven up before them. Some of theſe ſtones are 2 or 3 tons weight, and have left a track of ſeveral rods behind them; having at leaſt a common cart-load of clay before them. The ſhore of the cove is lined with theſe ſtones, which, it would ſeem, have crawled out of the water.—*Morſe.*

BRIDGETOWN, Cumberland county, New-Jerſey, lies on both ſides Cohanzie Creek, 20 miles from its mouth; and veſſels of 100 tons can come up here. It has about 50 houſes, and a briſk trade. Another Bridgetown is on the great ſtage road, between Philadelphia and New-York, 6 miles W. of Elizabeth town.—*ib.*

BRIDGETOWN, a poſt town in Queen Annes co. Maryland, lies on the weſtern ſide of Tuckahoe Creek, 8 miles E. from Centreville, as far S. E. from Church Hill, and 65 S. W. from Philadelphia.

Alſo the name of a town in Kent co. in the ſame ſtate, ſituated on the N. bank of Cheſter River, (which ſeparates this county from that of Ann) 7 miles S. E. from Croſs Roads; and 4 ſoutherly from Newmarket. —*Morſe.*

BRIDGEWATER, a townſhip in Grafton co. New-Hampſhire, incorporated in 1769, and contains 281 inhabitants.—*ib.*

Bridgewater, a townſhip in Somerſet co. New-Jerſey, which contains 2,578 inhabitants, including 377 ſlaves.—*ib.*

Bridgewater, a conſiderable townſhip in Plymouth co. Maſſachuſetts, containing 4975 inhabitants; 5 miles N. E. from Raynham; about 30 miles E. of S. from Boſton, in which large quantities of hard ware, nails, &c. are manufactured.—*ib.*

Bridgewater, a townſhip in Windſor co. Vermont, about 55 miles N. E. of Bennington, containing 293 inhabitants.—*ib.*

BRIDPORT, a townſhip in Addiſon co. Vermont, on the E. ſhore of Lake Champlain; about 72 miles N. N. W. from Bennington. It has 449 inhabitants. —*ib.*

BRIMFIELD, a townſhip in Hampſhire co. Maſſachuſetts, ſituated E. of Connecticut River; having 1211 inhabitants; 34 miles S. E. of Northampton, and 75 W. of Boſton.—*ib.*

BRINDLEY (James), was born at Tunſted, in the pariſh of Wormhill, Derbyſhire, in 1716. His father was a ſmall freeholder, who diſſipated his property in company and field amuſements, and neglected his family. In conſequence, young Brindley was left deſtitute of even the common rudiments of education, and till the age of 17 was caſually employed in ruſtic labours. At that period he bound himſelf apprentice to one Bennet, a mill-wright at Macclesfield, in Cheſhire, where his mechanical genius preſently developed itſelf. The maſter being frequently abſent, the apprentice was often left for weeks together to finiſh pieces of works concerning which he had received no inſtruction; and Bennet, on his return, was often greatly aſtoniſhed to ſee improvements in various parts of mechaniſm, of which he had no previous conception. It was not long before the millers diſcovered Brindley's merits, and preferred him in the execution of their orders to the maſter or any other workman. At the expiration of his ſervitude, Bennet being grown into years, he took the management of the buſineſs upon himſelf, and by his ſkill and induſtry contributed to ſupport his old maſter and his family in a comfortable manner.

In proceſs of time Brindley ſet up as a mill-wright on his own account; and by a number of new and ingenious contrivances greatly improved that branch of mechanics, and acquired a high reputation in the neighbourhood. His fame extending to a wider circle, he was employed, in 1752, to erect a water-engine at Clifton, in Lancaſhire, for the purpoſe of draining ſome coal mines. Here he gave an eſſay of his abilities in a kind of work for which he was afterwards ſo much diſtinguiſhed, driving a tunnel under ground through a rock nearly 600 yards in length, by which water was brought out of the Irwell for the purpoſe of turning a wheel fixed 30 feet below the ſurface of the earth. In 1755 he was employed to execute the larger wheels for a ſilk mill at Congleton; and another perſon, who was engaged to make other parts of the machinery, and to ſuperintend the whole, proving incapable of completing the work, the buſineſs was entirely committed to Brindley; who not only executed the original plan in a maſterly manner, but made the addition of many curious and valuable improvements, as well in the conſtruction of the engine itſelf, as in the method of making the wheels and pinions belonging to it. About this time, too, the mills for grinding flints in the Staffordſhire potteries received various uſeful improvements from his ingenuity.

In the year 1756 he undertook to erect a ſteam engine, upon a new plan, at Newcaſtle-under-Line; and he was, for a time, very intent upon a variety of contrivances for improving this uſeful piece of mechaniſm. But from theſe deſigns he was, happily for the public, called away to take the lead in what the event has proved to be a national concern of capital importance—the projecting the ſyſtem of canal navigation. The Duke of Bridgewater, who had formed his deſign of carrying a canal from his coal-works at Worſley to Mancheſter, was induced by the reputation of Mr Brindley to conſult him on the execution of it; and having the ſagacity to perceive, and ſtrength of mind to confide in, the original and commanding abilities of this ſelf-taught genius, he committed to him the management of the arduous undertaking. The nature of this enterpriſe has already been deſcribed (*Encycl.* vol. IV. p. 80); it is enough here to mention, that Mr Brindley, from the very firſt, adopted thoſe leading principles, in the projecting of theſe works, which he ever after adhered to, and in which he has been imitated by all ſucceeding artiſts. To preſerve as much as poſſible the level of his canals, and to avoid the mixture and interference of all natural ſtreams, were objects at which he conſtantly aimed. To accompliſh theſe, no labour or expence was ſpared; and his genius ſeemed to delight in overcoming all obſtacles by the diſcovery of new and extraordinary contrivances.

The moſt experienced engineers upon former ſyſtems were amazed and confounded at his projects of aqueduct bridges over navigable rivers, mounds acroſs deep valleys, and ſubterraneous tunnels; nor could they believe in the practicability of ſome of theſe ſchemes till they ſaw them effected. In the execution, the ideas he followed were all his own; and the minuteſt, as well as the greateſt, of the expedients he employed, bore the ſtamp of originality. Every man of genius is an enthuſiaſt. Mr Brindley was an enthuſiaſt in favour of the ſuperiority of canal navigations above thoſe of rivers; and this triumph of art over nature led him to view with a ſort of contempt the winding ſtream, in which the lover of rural beauty ſo much delights. This ſentiment he is ſaid to have expreſſed in a ſtriking manner at an examination before a committee of the Houſe of Commons, when, on being aſked, after having made ſome contemptuous remarks relative to rivers, what he conceived they were created for? he anſwered, "to feed navigable canals." A direct rivalry with the navigation of the Irwell and Merſey was the bold enterprize of his firſt great canal; and ſince the ſucceſs of that deſign, it has become common, all over the kingdom, to ſee canals accompanying, with inſulting parallel, the courſe of navigable rivers.

After the ſucceſsful execution of the Duke of Bridgewater's canal to the Merſey, Mr Brindley was employed in the revived deſign of carrying a canal from that

Brindley.

river to the Trent, through the counties of Cheſter and Stafford. This undertaking commenced in the year 1766; and from the great ideas it opened to the mind of its conductor, of a ſcheme of inland navigation which ſhould connect all the internal parts of England with each other, and with the principal ſea-ports, by means of branches from this main ſtem, he gave it the emphatical name of the *grand trunk*. In executing this, he was called upon to employ all the reſources of his invention, on account of the inequality and various nature of the ground to be cut through: in particular, the hill of Harecaſtle, which was only to be paſſed by a tunnel of great length, bored through ſtrata of different conſiſtency, and ſome of them mere quickſand, proved to be a moſt difficult, as well as expenſive, obſtacle, which, however, he completely ſurmounted. While this was carrying on, a branch from the grand trunk, to join the Severn near Bewdley, was committed to his management, and was finiſhed in 1772. He alſo executed a canal from Droitwich to the Severn; and he planned the Coventry canal, and for ſome time ſuperintended its execution; but on account of ſome difference in opinion he reſigned that office. The Cheſterfield canal was the laſt undertaking of the kind which he conducted, but he only lived to finiſh ſome miles of it. There was, however, ſcarcely any deſign of canal-navigation ſet on foot in the kingdom, during the latter years of his life, in which he was not conſulted, and the plan of which he did not either entirely form, or reviſe and improve. All theſe it is needleſs to enumerate; but, as an inſtance of the vaſtneſs of his ideas, it may be mentioned, that, on planning a canal from Liverpool to join that of the duke of Bridgewater at Runcorn, it was part of his intention to carry it, by an aqueduct bridge, acroſs the Merſey, at Runcorn Gap, a place where a tide, ſometimes riſing fourteen feet, ruſhes with great rapidity through a ſudden contraction of the channel. As a mechanic and engineer, he was likewiſe conſulted on other occaſions; as with reſpect to the draining of the low lands in different parts of Lincolnſhire and the Iſle of Ely, and to the cleanſing of the docks of Liverpool from mud. He pointed out a method, which has been ſucceſsfully practiſed, of building ſea-walls without mortar; and he was the author of a very ingenious improvement of the machine for drawing water out of mines by the contrivance of a loſing and a gaining bucket.

The intenſity of application which all his various and complicated employments required, probably ſhortened his days; as the number of his undertakings, in ſome degree, impaired his uſefulneſs. He fell into a kind of chronic fever, which, after continuing ſome years, with little intermiſſion, at length wore out his frame, and put a period to his life on September 27. 1772, in the 56th year of his age. He died at Tunhurſt, in Staffordſhire, and was buried at New Chapel in the ſame county.

In appearance and manners, as well as in acquirement, Mr Brindley was a mere peaſant. Unlettered, and rude of ſpeech, it was eaſier for him to deviſe means for executing a deſign than to communicate his ideas concerning it to others. Formed by nature for the profeſſion he aſſumed, it was there alone that he was in his proper element; and ſo occupied was his mind with his buſineſs, that he was incapable of relaxing in any of the common amuſements of life. As he had not the ideas of other men to aſſiſt him, whenever a point of difficulty in contrivance occurred, it was his cuſtom to retire to his bed, where, in perfect ſolitude, he would lie for one, two, or three days, pondering the matter in his mind till the requiſite expedient had preſented itſelf. This is that true inſpiration which poets have almoſt excluſively arrogated to themſelves, but which men of original genius in every walk are actuated by, when, from the operation of the mind acting upon itſelf, without the intruſion of foreign notions, they create and invent.

Brindley || Briſſot.

A remarkably retentive memory was one of the eſſential qualities which Mr Brindley brought to his mental operations. This enabled him to execute all the parts of the moſt complex machine in due order, without any help of models or drawings, provided he had once accurately ſettled the whole plan in his mind. In his calculations of the powers of machines, he followed a plan peculiar to himſelf; but, indeed, the only one he could follow without inſtruction in the rules of art. He would work the queſtion ſome time in his head, and then ſet down the reſult in figures. Then taking it up in this ſtage, he would again proceed by a mental operation to another reſult; and thus he would go on by ſtages till the whole was finiſhed, only making uſe of figures to mark the ſeveral reſults of his operations. But though, by the wonderful powers of native genius, he was thus enabled to get over his want of artificial method to a certain degree, yet there is no doubt that when his concerns became extremely complicated, with accounts of various kinds to keep, and calculations of all ſorts to form, he could not avoid that perplexity and embarraſſment which a readineſs in the proceſſes carried on by pen and paper can alone obviate. His eſtimates of expence have generally proved wide of reality; and he ſeems to have been better qualified to be the contriver, than the manager, of a great deſign. His moral qualities were, however, highly reſpectable. He was far above envy and jealouſy, and freely communicated his improvements to perſons capable of receiving and executing them; taking a liberal ſatisfaction in forming a new generation of engineers able to proceed with the great plans in the ſucceſs of which he was ſo deeply intereſted. His integrity and regard to the advantage of his employers were unimpeachable. In fine, the name of Brindley will ever keep a place among that ſmall number of mankind who form eras in the art or ſcience to which they devote themſelves, by a large and durable extenſion of its limits.

BRISSOT (J. P.), acted ſo conſpicuous a part in the French revolution, that a fair detail of the principal events of his life would undoubtedly be acceptable to all our readers. A fair detail, however, of ſuch a life, we believe it impoſſible at preſent to give; for characters like Briſſot's are almoſt always miſrepreſented both by their friends and by their enemies; and till the troubles which they have excited, or in which they have been engaged, have long ſubſided, the impartial truth is nowhere to be found.

In a fulſome panegyric, under the denomination of *The Life of J. P. Briſſot*, ſaid to be written by himſelf, we are told, that he was born January 14, 1754, and that his father was a *traiteur*, or "the keeper of an eating-houſe," but in what place we are not informed.

Our

Briſſot.

Our author, however, aſſures us, that the old man was in eaſy circumſtances, and that he employed all the means reſulting from them to give to his numerous family a good education. The ſubject of this memoir was intended for the bar; but not reliſhing the ſtudies neceſſary to fit him for the profeſſion of the law, or, if we chooſe to believe him, having a mind too *pure* and *upright* for the ſtudy of *chicane*, he relinquiſhed the purſuit after five years of drudgery!

To relieve his wearineſs and diſguſt, he applied himſelf, he ſays, to literature and the ſciences. The ſtudy of the languages was above all others his favourite purſuit. Chance brought him acquainted with two Engliſhmen on their travels through France: he learned their language; and this circumſtance, he tells us, decided his fate.

“ It was at the commencement of my paſſion for that language (continues he) that I made the metamorphoſis of a diphthong in my name, which has ſince been imputed to me as ſo heinous a crime. Born the thirteenth child of my family, and the ſecond of my brothers in it, I bore, for the ſake of diſtinction, according to the cuſtom of Beauce, the name of a village in which my father poſſeſſed ſome landed property. This village was called *Ouarville*, and Ouarville became the name by which I was known in my own country. A fancy ſtruck me that I would caſt an Engliſh air upon my name: and accordingly I ſubſtituted, in the place of the French diphthong *ou*, the *w* of the Engliſh, which has preciſely the ſame ſound.” For this puerile affectation, which was certainly not criminal, he juſtifies himſelf by the example of the literati of the 16th and 17th centuries, who made no ſcruple of Greciſing and Latiniſing their appellatives.

Having proſecuted his ſtudies for two years, he had an application from the Engliſh proprietor of a paper then much in circulation, and intitled *Le Courier de l'Europe*. This man having drawn upon himſelf an attack from government, felt and yielded to the neceſſity of printing his paper at Boulogne-ſur-mer. It was his wiſh to render it intereſting to the French in the department of miſcellaneous intelligence; which he therefore wiſhed to ſubmit to the ſuperintendency and arrangement of Briſſot, who repreſents himſelf as for ſome moments heſitating. The profeſſion of a journaliſt, ſubject to a licenſer, was repugnant to his principles; yet it ſecured his independence, and put into his power the means of proſecuting an inveſtigation of conſtitutions and of the ſciences. After ſome ridiculous reaſoning from the original ſtations of *Bayle*, *Poſtel*, and *Rouſſeau*, he at laſt accepted of the employment, and became enamoured of it, “ becauſe (ſays he) it enabled me to ſerve talents and virtue, and, as it were, to inoculate the French with the principles of the Engliſh conſtitution.

This employment, however, did not laſt for any length of time. The plan of the proprietor of the *Courier* was overthrown by adminiſtration, and Briſſot quitted Boulogne to return to his firſt ſtudies. Having informed us of this fact, he makes an extravagant pretence to unſullied virtue, and calls upon the inhabitants of the city which he had left to bear witneſs, not only that he had *no vices*, but that he had not even the *ſeeds* of any one of the vices which his adverſaries, it ſeems, had laid to his charge.

“ Doubtleſs (ſays he), too eager to publiſh my ideas, I conceived that the proper moment had arrived, and I felt an inclination to commence with an important work. Revolting, from the very inſtant of my beginning to reflect, againſt religious and political tyranny, I ſolemnly proteſted, that thenceforward I would conſecrate my whole life to their extirpation. Religious tyranny had fallen under the redoubled ſtrokes of Rouſſeau, of Voltaire, of Diderot, and of D'Alembert. It became neceſſary to attack the ſecond;” and this was a taſk which the vanity of Briſſot led him to conſider as reſerved for him.

What Voltaire and his friends meant by religious tyranny, and how they conducted their attacks againſt it, are matters, alas! too well known to all Europe; and as our author choſe theſe philoſophers for his guides, we might infer, without much degree of miſtake, what he underſtood by political tyranny, and by what means he meditated its extirpation. But he has not left us to make this diſcovery by inference.

“ It became neceſſary (ſays he) to break in pieces the political idol, which under the name of *monarchy*, practiſed the moſt violent deſpotiſm; but to attack it openly, was to expoſe the aſſailant without the poſſibility of ſerving mankind. It was by a ſide blow that it was to be wounded moſt effectually;” and therefore he reſolved to begin his operations by attacking ſome of thoſe abuſes which might be reformed without apparently ſhaking the authority of the prince.

Our readers, at leaſt the ſober part of them, will probably think, that this mode of attack is not peculiar to Briſſot, but that it has been practiſed, or attempted to be put in practice, by aſpiring demagogues in all ages and countries, who have uniformly begun their career of innovation by exciting the public mind againſt thoſe abuſes in government, of which the exiſtence cannot wholly be denied. The ſubject to which our author thought fit to call the attention of his countrymen, was the criminal juriſprudence: a ſubject, ſays he, which, with the exception of ſome particulars that had been ſucceſsfully inveſtigated by Beccaria and Servan, no writer had thoroughly conſidered in a philoſophical point of view. Thinking himſelf fully equal to this taſk, he drew up a general plan; and in the year 1780 publiſhed his Theory of Criminal Laws, in two vols 8vo. This work, favourably received by foreigners, applauded by ſome journaliſts, and pulled to pieces by others, procured him the friendſhip of the warmeſt advocates for human liberty, in whoſe opinion the defects of his plan were highly pardonable, on account of the energy conſpicuous in his remarks. This publication was ſoon followed by two diſcourſes which gained the prize in 1782 at the Academy of Chalons-ſur-Marne; the one upon the reform of the criminal laws, and the other on the reparation due to innocent perſons unjuſtly accuſed.

It is natural to ſuppoſe that the government beheld with an evil eye theſe writings, which, under pretext of dragging into light the abuſes of the criminal laws, inſinuated dangerous principles on the nature of government in general.

His next work was intitled, *A Philoſophical Library of the Criminal Laws*, in 10 vols; the true object of which was to diſſeminate in France thoſe principles of liberty which guided the Engliſh and the Americans in framing and expounding their laws.

But the ſtudy of legiſlation and politics had not entirely drawn him off from that of other ſciences; ſuch as chemiſtry, phyſics, anatomy, theology, &c. Theſe he conſtantly cultivated with ardour; but acknowledges that in each he met with obſcurities, and that in every quarter truth eſcaped from his reſearches. He therefore ſat down to inveſtigate the nature of truth, and the proper method of attaining to it in every department of reſearch; and the reſult of his labours was a kind of *novum organum*, by which he ſeems to have expected that Bacon's work would be buried in oblivion; and to this important volume he gave the title of *Concerning Truth;* or *Thoughts on the Means of attaining Truth in all the Branches of Human Knowledge.* This volume was meant as nothing more than the introduction to a greater work, in which he propoſed to inveſtigate what is *certain* in knowledge and what *doubtful*, and then to ſtrike the balance of the account.

He was prevented, however, from completing his plan, which he regrets exceedingly; for, as he affirms, with *becoming modeſty*, his work would certainly have amended its readers! But the French government happened to think otherwiſe; his aim, which, he ſays, was to lead mankind to reflect on their rights, was perceived, and he was accuſed to the miniſter as a ſeditious writer. The career of genius was ſtopped by the dread of the Baſtile; and he was obliged to take refuge in London. There it was his wiſh to create *a univerſal confederation of the friends of liberty and truth*, and to eſtabliſh a *centre of correſpondence and union* with the learned and the politicians of Europe. This dark deſign, however, was fruſtrated by the treachery, as it would appear, of his aſſociates, who had bound themſelves, he ſays, by the moſt *ſacred oaths*, to aſſiſt him, and had offered to ſign articles *even with their own blood.*

Finding himſelf unable to proceed directly to the object which he had in view, he reſolved to *enlighten his* countrymen gradually, and to begin with exciting their love and admiration of the Engliſh conſtitution. That conſtitution, which he had inveſtigated on the ſpot, appeared to him a model for thoſe ſocieties which were deſirous of changing their form of government. It was but little known, he ſays, in France (the work of *De Lolme* being at that time only in the hands of the learned); and to make it known was to make it beloved, was to render it deſired. But the French miniſters ſtood upon their guard, and it became neceſſary to *deceive* them. He reſolved therefore to bring forward a journal, written actually in London, and profeſſing to contain only a *deſcription of the ſciences and arts of England*, whilſt the greater part of it was to be occupied in reality by an inveſtigation of the *Engliſh conſtitution.*

After many difficulties, the miniſtry granted a privilege for this journal, being publiſhed in London, to be reprinted in Paris; and it firſt appeared in 1784. "In the twelve numbers which have been publiſhed (ſays the author), the friends of liberty muſt have perceived, that if, on the one ſide, I endeavoured to inculcate more juſt ideas than had hitherto been entertained concerning this celebrated iſland; ſo, on the other, I reſolutely made my advances toward that important end which has perpetually preſided over all my labours, *the univerſal emancipation of men.*"

His affairs calling him at this time to Paris, he was arreſted and conveyed to the Baſtile on the 12th of July 1784. In this conduct of the government we cannot perceive any thing very tyrannical or arbitrary, ſince he confeſſes, that in the 16th page of the firſt number of his Journal, he had ſuffered the *ſecret and favourite aim*, which always guided his pen, to become diſcernible. He was, however, diſcharged from priſon on the 5th of September, and returned with increaſed zeal to his former employments.

"This perſecution (ſays he), far from extinguiſhing the ardour of my wiſhes to inculcate the principles of freedom, ſerved only to inflame it the more." Accordingly, in 1785, he publiſhed two letters to the Emperor Joſeph II. *concerning the right of emigration, and the right of people to revolt.* The firſt of theſe letters, which, though well known in Germany, were in France ſuppreſſed by the *police*, was occaſioned by what the author calls the ridiculous and barbarous edict againſt emigration; and the ſecond by the puniſhment of *Horiah* the chief of the *Walachian* inſurgents. In this laſt letter he lays it down as a maxim, that all people under ſuch a government as that of the *Walachians*, have from nature a ſacred *right* to revolt, a right which they can and ought to exerciſe. In the ſame ſpirit he brought out, in 1786, his Philoſophical Letters on the Hiſtory of England, in 2 vols, and A Critical Examination of the Travels of the Marquis de Chatelleux in North America.

The French revolution appearing to him extremely diſtant, notwithſtanding all his efforts to haſten it, he reſolved to leave France for the purpoſe of ſettling in America. His project received the approbation of ſeveral, whoſe ſentiments were congenial with his own. But as it was thought imprudent to tranſport numerous families to a country ſo far off, without thoroughly knowing it, Briſſot was engaged to proceed thither, to examine the different places, to obſerve the inhabitants, and to diſcover where and in what manner the eſtabliſhment they had propoſed might be moſt advantageouſly fixed. He had ſome time before inſtituted a ſociety at Paris for accompliſhing the abolition of the negro trade, and for ſoftening the condition of the ſlaves. At the period of his departure, this ſociety conſiſted of a conſiderable number of diſtinguiſhed members, and he was commiſſioned to carry the firſt fruits of their labours to America. His ſtay there, however, was not ſo long as he was deſirous of making it. In the beginning of 1789 he was recalled by the news of the French revolution, which he conceived might probably produce a change in his own meaſures and in thoſe of his friends. This idea added to other circumſtances, accelerated his return. The fire had blazed forth in his native country. Hope (ſays he) animated every heart; the moſt diſtinguiſhed champions had engaged in the conteſt; I too became deſirous to break a lance, and I publiſhed my *Plan of Conduct for the Deputies of the People.*"

This, and other works of a ſimilar kind, of which he loudly boaſts the merits, raiſed him high in the favour of the republican part of the nation, and he became preſident of his diſtrict; where he acted, according to his own account, with great uprightneſs in the municipality, in the firſt committee of enquiries, and as an elector. At laſt he became a member, firſt of the *National Aſſembly*, and after its diſſolution, of the *Sanguinary*

nary Convention ; and by ſome means or other got to be the leader of a party called ſometimes the *Girondiſts*, and ſometimes the *Briſſotines*. From that period the principal events of his life were involved with the public tranſactions of the nation, of which we have given an account in the *Encyclopædia* under the title Revolution (ſee that article, n° 101—182.) The Girondiſt faction was denounced by the Mountain, and Briſſot ſuffered by the guillotine on the 30th of November 1793. He fell indeed by a very unjuſt ſentence ; but his fall was the natural conſequence of that anarchical tyranny under which no man had contributed more than he to ſubject his native country.

BRISTOL, a townſhip in Lincoln co. Diſtrict of Maine, having 1718 inhabitants ; diſtant 204 miles N. E. from Boſton, and 8 N. of Pemaquid Point. —*Morse.*

Bristol, a county in the ſouthern part of Maſſachuſetts, E. of a part of the ſtate of Rhode Iſland. It has 15 townſhips, of which Taunton is the chief; and 31,709 inhabitants. The great ſachem Phillip reſided here ; and it was called by the Indians *Pawkunnawkutt ;* from which the nation derived the name ; but were ſometimes ſtyled the *Wampo-noags.—ib.*

Bristol, *Co.* in Rhode Iſland ſtate, contains the townſhips of Briſtol, Warren, and Barrington ; having 3211 inhabitants, incluſive of 98 ſlaves. It has Briſtol co in Maſſachuſetts, on the N. E. and Mount Hope bay E.—*ib.*

Bristol, a ſea-port town, and chief of the above county, lies on the weſtern ſide of the peninſula called Briſtol neck, and on the E. ſide of Briſtol bay ; including Popaſquaſh neck, and all the N. and E. part of Briſtol neck, to Warren, N. ; and to Mount Hope bay, E. It is about 3 miles from Rhode Iſland ; the ferry from the S. end of the townſhip being included, which is little more than half a mile broad ; 13 miles northerly from Newport, 24 S. E. from Providence, and 63 from Boſton.—Briſtol ſuffered greatly by the ravages of the late war ; but is now in a very flouriſhing ſtate, having 1406 inhabitants, incluſive of 64 ſlaves. It is beautiful for ſituation—a healthful climate—rich ſoil, and a commodious, ſafe harbor. Onions, in conſiderable quantities, and a variety of proviſions and garden ſtuff, are raiſed here for exportation. N. lat. 40. 40.—*ib.*

Bristol, a townſhip in Hartford co. Connecticut, 16 miles W. of the city of Hartford.—*ib.*

Bristol, a town in Bucks co. Pennſylvania, 11 miles S. S. E. from Newtown, and 20 N. E. from Philadelphia. It ſtands on Delaware River, oppoſite Burlington, in New-Jerſey ; and has about 50 or 60 houſes. It is a great thoroughfare, and is noted for its mills of ſeveral kinds.—*ib.*

Bristol, a townſhip in Philadelphia county.—*ib.*

Bristol, a ſmall town in Charles county, Maryland.—*ib.*

Bristol, a townſhip in Addiſon co. Vermont, E. of Vergennes, having 211 inhabitants.—*ib.*

Bristol *Bay*, on the N. W. coaſt of N. America, is formed by the peninſula of Alaſka on the S. and S. E. and by Cape Newnham on the N. ; and is very broad and capacious. A river of the ſame name runs into it from the E.—*ib.*

BROOKFIELD, in the S. W. part of Worceſter co. Maſſachuſetts, is among the firſt towns as to age, wealth and numbers, in the county ; containing 3100 inhabitants. The great poſt road from Boſton to N. York runs through it. It is 64 miles W. of Boſton and 27 W of Worceſter. The Indian name of this town was *Quaboag*. The river which ſtill retains the name paſſes through it ; and like its other ſtreams and ponds, abounds with various kinds of fiſh. Here is iron ore, and large quantities of ſtone which yield copperas, and have a ſtrong vitriolic quality. This town was ſettled by people from Ipſwich, in 1660, and was incorporated in 1673.—*ib.*

Brookfield, a townſhip in Orange co. Vermont, has 421 inhabitants, and lies 80 miles northerly from Bennington.—*ib.*

Brookfield, a townſhip in Lincoln co. diſtrict of Maine, 14 miles above Norridgewalk on Kennebeck River, and was formerly called *Seven mile Brook.—ib.*

Brookfield, a town in Montgomery co. New-York. By the ſtate cenſus of 1796, 160 of its inhabitants are electors.

Brookfield, a townſhip in Fairfield co. Connecticut, 6 miles N. N. E. from Danbury.—*ib.*

BROOKHAVEN, a townſhip in Suffolk co. Long Iſland, New-York, containing 3,224 inhabitants. Of theſe 233 are ſlaves ; and by the ſtate cenſus of 1796, 535 only are electors. The compact part of the town contains about 40 houſes, an Epiſcopalian, and a Preſbyterian church. It is 60 miles E. of New-York.—*ib.*

BROOKLYN, a townſhip in Kings co. New-York, on the W. end of Long Iſland, having 1603 inhabitants ; of theſe 405 are ſlaves ; and 224 are electors, by the ſtate cenſus of 1796. Here are a Preſbyterian church, a Dutch Reformed church, a powder magazine, and ſome elegant houſes which lie chiefly on one ſtreet. Eaſt River, near a mile broad, ſeparates the town from New-York.—*ib.*

Brooklin, a townſhip in Wyndham co. Connecticut, about 20 miles N. of Norwich.—*ib.*

BROTHERTON, an Indian village adjoining New-Stockbridge, (N. York) inhabited by about 150 Indians, who migrated from different parts of Connecticut, under the care of the Rev. Mr Occom. Theſe Indians receive an annuity of 2160 dollars, which ſum is partly appropriated to the purpoſe of maintaining a ſchool, and partly to compenſate a ſuperintendant, to tranſact their buſineſs, and to diſpoſe of the remainder of their money for their benefit.—*ib.*

BROWN (Dr John), author of the *Elementa Medicinæ*, &c. was born in the village of Dunſe, or, as ſome ſay, Lintlaws, in the county of Berwick, in the year 1735-6. His parents were of mean condition, but much reſpected in the neighbourhood for the integrity of their lives. His father gained his livelihood in the humble capacity of a day-labourer ; while his mother contributed her ſhare towards the ſupport of the family by the profits ariſing from a milch cow.

Such were the perſons who, in an obſcure part of the country, gave birth to a ſon deſtined, at a future period, to make a diſtinguiſhed figure in the republic of letters ; and from whom originated a ſyſtem of the animal economy, which, whatever be its real merits, has undoubtedly produced a conſiderable revolution in the practice of medicine.

At the age of three or four years, young Brown was put to a reading ſchool in Dunſe, which he himſelf commemorates as the place rather of his education than of his nativity. Here, under the tuition of an old woman, he very early began to exhibit marks of that ſtrength of mind for which he was afterwards ſo eminently diſtinguiſhed. In the ſhort period of a year he became able to read with facility any part of the Bible, and acquired over his claſs-fellows that ſuperiority which he ever after maintained both at ſchool and college.

It was almoſt immediately after his entrance into this ſchool, that his inſatiable deſire of reading commenced; and ſo unremitting was his application, that he is ſaid never to have been found, even at thoſe hours which children much more advanced in life devote to amuſement, without a book in his hand.

While he was making this rapid progreſs in the rudiments of literature, he ſuffered what muſt have appeared to be a very heavy loſs in the death of his father; but his mother ſoon afterwards married a worthy man of the ſame name, whoſe care and attention ſupplied the place of a father to her ſon. This man being a weaver, deſigned to educate his ſon-in-law to the ſame buſineſs, and began to inſtruct him in his art when he was about nine years of age, but the taſte which young Brown had already acquired for letters, made him look with diſguſt on the inſipid employment of a weaver. His ſtep-father was no tyrant, and his mother was affectionate. They were both proud of the talents which at ſo early a period of life had appeared in their ſon, and they felt no inclination to ſtruggle with the invincible averſion which he expreſſed to the buſineſs for which they intended him.

Another circumſtance, however, contributed in no ſmall degree to make them recal their original reſolution. They were both of that ſect of religioniſts which in Scotland are called Seceders (ſee Seceders, *Encyl.*); and it was ſuggeſted to them by ſome perſons of their own perſuaſion, who had remarked the uncommon abilities of the boy, that he might one day prove an able ſupport and promoter of their tenets as a preacher. He was accordingly, much to his ſatisfaction, taken away from the buſineſs to which he had conceived ſuch a diſtaſte, and ſent to the grammar-ſchool of Dunſe, which was taught at that time by a gentleman of the name of Cruickſhank, eminent for his grammatical knowledge. Here he appears to have ſpent ſome years with uncommon advantage and happineſs; during which he was eſteemed by all the country round as a kind of prodigy. Like Johnſon, and many other men of the higheſt celebrity, he united in the ſame perſon uncommon powers of mind, with no leſs ſtrength of body, as indeed his appearance indicated; and in his youth he inſured his own perſonal importance among his ſchool-fellows, by excelling them not leſs in athletic exerciſes than in the taſks preſcribed by their maſter. He was particularly fond, when a boy, of practiſing the pugiliſtic art; and indeed until the laſt period of his life he was obſerved by his friends always to view an exhibition of that kind with peculiar reliſh. He alſo prided himſelf much in being a ſtout walker; and mentions his having, in one day, accompliſhed, when but fifteen years of age, a journey of fifty miles between Berwick-upon-Tweed and Morpeth in Northumberland. When farther advanced in life, he travelled on foot from four in the afternoon of one day to two in the afternoon of next day, with the ſhort interval of one hour's reſt! But as one of his biographers very juſtly obſerves, "we have ſeen that he could make a more rational uſe of his ſtrength than merely to ſtake it againſt time and ſpace.*"

His early years while at ſchool were marked by the moſt rigid attachment to his ſect. So ſtrict indeed were his religious ſentiments, if a boy of ten or eleven can be ſaid to have any ſentiments deſerving to be called religious, that he would have conceived the holding of any communion with the eſtabliſhed church as a kind of profanation. An event, however, happened, ſome time between the eleventh and thirteenth years of his age, which produced a total and unexpected revolution in his religious opinions. At a meeting of the provincial ſynod of Merſe and Teviotdale, he was prevailed upon, though not without manifeſting much reluctance, to accompany a party of his ſchool-fellows to the pariſh church of Dunſe. The conſequence of this tranſgreſſion, as he had dreaded, was an immediate ſummons to appear before the ſeſſion of the Seceding congregation; to which, through pride, not chooſing to attend, in order to preclude a formal expulſion, he voluntarily abjured their tenets, and openly avowed his apoſtacy to the eſtabliſhment.

All changes in religion which are not the conſequence of candid inveſtigation are dangerous. He who leaves one ſect he knows not why, will quickly abandon, with as little reaſon, that to which in a fit of paſſion he had haſtily joined himſelf. From the moment of his quitting the communion of the Seceders, Brown's religious ardour ſuffered a gradual abatement; and though, to pleaſe his mother, he continued to proſecute his ſtudies with a view to the office of a clergyman in the church of Scotland, his opinions became daily more and more lax, and his life of courſe leſs and leſs regular. It was, however, a conſiderable time before he admitted, in their full extent, thoſe principles of irreligion which he afterwards avowed; for upon his firſt peruſing the Eſſays of Mr Hume, though his own zeal was then much cooled, he expreſſed great indignation at their dangerous tendency.

At the age of twelve years he had been employed by Mr Cruickſhank as a kind of uſher in the ſchool of Dunſe; and that gentleman having declared that his knowledge of the Latin language was equal to his own, his fame as a ſcholar was ſo ſpread over the country, that at the age of thirteen he was entruſted with the education of a gentleman's ſon in the neighbourhood, when he quitted the ſchool and his beloved maſter. In his new ſituation, however, he remained not long. Dr Beddoes conjectures, that to the ſtiffneſs of pedantry he added the ſourneſs of a bigot, and was therefore a diſagreeable inmate of the family. That a boy of thirteen, proud of his talents, and prouder of his learning, ſhould have the ſtiffneſs of a pedant, is indeed extremely probable; it was the natural conſequence of the praiſe with which he had been honoured by Mr Cruickſhank: but there is reaſon to believe that of his original bigotry few traces now remained. The real cauſe of his diſmiſſion from the family, we are aſſured, was his pride; and as it muſt have been the pride of parts, it confirms the firſt part of Dr Beddoes's conjecture.

It ſeems he was much diſpleaſed that, when company

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* Dr Be does.

of debility, termed *direct* and *indirect*, which, according to Brown are the cauſe of all diſeaſes. If the quantity of ſtimulus, or exciting power, is proportioned to the quantity of excitability, that is, if no more excitement is drawn forth than is equal to the quantity of excitability produced, the human frame will be in a ſtate of health, juſt as the fire will be in a vigorous ſtate when no more air is blown in than is ſufficient to conſume the freſh ſupply of fuel conſtantly poured down by the tube behind. If a ſufficient quantity of ſtimulus is not applied, or air not blown in, the excitability in the man, and the fuel in the fire, will accumulate, producing direct debility; for the man will become weak, and the fire low. Carried to a certain degree, they will occaſion death to the firſt, and extinction to the laſt. If, again, an over proportion of ſtimulus be applied, or too much air blown in, the excitability will ſoon be waſted, and the matter of fuel almoſt ſpent. Hence will ariſe indirect debility, producing the ſame weakneſs in the man, and lowneſs in the fire, as before, and equally terminating, when carried to a certain degree, in death and extinction.

‘ As all the diſeaſes of the body, according to Dr Brown, are occaſioned by direct or indirect debility, in conſequence of too much or too little ſtimuli, ſo all the defects of the fire muſt ariſe from direct or indirect lowneſs, in conſequence of too much or too little air blown into it. As Brown taught that one debility was never to be cured by another, but both by the more judicious application of ſtimuli, ſo will be found the caſe in treating the defects of the fire. If the fire has become low, or the man weak, by the want of the needful quantity of ſtimulus, more muſt be applied, but very gently at firſt, and increaſed by degrees, leſt a ſtrong ſtimulus applied to the accumulated excitability ſhould produce death; as in the caſe of a limb benumbed with cold (that is, weakened by the accumulation of its excitability in conſequence of the abſtraction of the uſual ſtimulus of heat), and ſuddenly held to the fire, which we know from experience is in danger of mortification, or as in the caſe of the fire becoming very low by the accumulation of the matter of fuel, when the feeble flame, aſſailed by a ſudden and ſtrong blaſt of air, would be overpowered and put out, inſtead of being nouriſhed and increaſed. Again, if the man or the fire have been rendered indirectly weak, by the application of too much ſtimulus, we are not ſuddenly to withdraw the whole, or even a great quantity of the exciting powers or air, for then the weakened life and diminiſhed flame might ſink entirely; but we are by little and little to diminiſh the overplus of ſtimulus, ſo as to enable the excitability, or matter of fuel, gradually to recover its proper proportion. Thus a man who has injured his conſtitution by the abuſe of ſpirituous liquors is not ſuddenly to be reduced to water alone, as is the practice of ſome phyſicians, but he is to be treated as the judicious Dr Pitcairn of Edinburgh is ſaid to have treated a Highland chieftain, who applied to him for advice in this ſituation. The Doctor gave him no medicines, and only exacted a promiſe of him, that he would every day put in as much wax into the wooden *queich*, out of which he drank his whiſky, as would receive the impreſſion of his arms. The wax thus gradually accumulating, diminiſhed daily the quantity of the whiſky, till the whole *queich* was filled with wax; and the chieftain was thus gradually, and without injury to his conſtitution, cured of the habit of drinking ſpirits.

‘ Theſe analogies might be purſued farther; but my object is ſolely to furniſh ſome general ideas, to prepare the reader for entering more eaſily into the Brunonian theory, which I think he will be enabled to do after peruſing what I have ſaid. The great excellence of that theory, as applied, not only to the practice of phyſic, but to the general conduct of the health, is, that it impreſſes on the mind a ſenſe of the impropriety and danger of going from one extreme to another. The human frame is capable of enduring great varieties, if time be given it, to accommodate itſelf to different ſtates. All the miſchief is done in the tranſition from one ſtate to another. In a ſtate of low excitement we are not raſhly to induce a ſtate of high excitement, nor when elevated to the latter, are we ſuddenly to deſcend to the former, but ſtep by ſtep, and as one who from the top of a high tower deſcends to the ground. From haſty and violent changes, the human frame always ſuffers; its particles are torn aſunder, its organs injured, the vital principle impaired, and diſeaſe, often death, is the inevitable conſequence.

‘ I have only to add, that though in this illuſtration of the Brunonian ſyſtem (written ſeveral years ago), I have ſpoken of a tube conſtantly pouring in freſh fuel, becauſe I could not otherwiſe convey to the reader a familiar idea of the power poſſeſſed by all living ſyſtems, to renew their excitability when exhauſted; yet it may be proper to inform the ſtudent, that Dr Brown ſuppoſed every living ſyſtem to have received at the beginning its determinate portion of excitability; and, therefore, although he ſpoke of the exhauſtion, augmentation, and even renewal of excitability, I do not think it was his intention to induce his pupils to think of it as a kind of fluid ſubſtance exiſting in the animal, and ſubject to the law by which ſuch ſubſtances are governed. According to him, excitability was an unknown *ſomewhat*, ſubject to peculiar laws of its own, and whoſe different ſtates we were obliged to deſcribe (though inaccurately) by terms borrowed from the qualities of material ſubſtances.’

“ The Brunonian ſyſtem has frequently been charged with promoting intemperance. The objection is ſerious; but the view already given of its principles ſhews it to be groundleſs. No writer had inſiſted ſo much upon the dependence of life on external cauſes, or ſo ſtrongly ſtated the inevitable conſequences of exceſs. And there are no means of promoting morality upon which we can rely, except the knowledge of the true relations between man and other beings or bodies. For by this knowledge we are directly led to ſhun what is hurtful, and purſue what is ſalutary: and in what elſe does moral conduct, as far it regards the individual, conſiſt? It may be ſaid that the author's life diſproves the juſtneſs of this repreſentation: his life, however, only ſhews the ſuperior power of other cauſes, and of bad habits in particular; and I am ready to acknowledge the little efficacy of inſtruction when bad habits are formed. Its great uſe conſiſts in preventing their formation; for which reaſon popular inſtruction in medicine would contribute more to the happineſs of the human ſpecies, than the complete knowledge of every thing which is attempted to be taught in education,

tion, as it is conducted at preſent. But though the principles of the ſyſtem in queſtion did not correct the propenſities of its inventor, it does not follow that they tend to produce the ſame propenſities in others."

BROWNSVILLE, or *Redſtone Old-fort*, is a flouriſhing poſt-town in Fayette co. Pennſylvania; on the S. eaſtern bank of Monongahela River; between Dunlap and Redſtone creeks; and next to Pittſburg is the moſt conſiderable town in the weſtern parts of the ſtate. The town is regularly laid out, contains about 100 houſes, an Epiſcopalian, and Roman Catholic church, a brewery and diſtillery. It is connected with Bridgeport, a ſmall village on the oppoſite ſide of Dunlap creek, by a bridge 260 feet long. Within a few miles of the town are 4 Friends' meeting-houſes, 24 griſt, ſaw, oil, and fulling mills. The trade and emigration to Kentucky, employ boat-builders here very profitably; above 100 boats of 20 tons each, are built annually. Byrd's Fort formerly ſtood here, on the S. ſide of the mouth of Redſtone Creek, in N. lat. 39. 58. W. long. 81 12½; 37 miles ſoutherly from Pittſburg; 13 S. by E. of Waſhington, and 341 W. of Philadelphia.—*Morſe.*

BRUCE (James, Eſq; F. R. S.), the celebrated Abyſſinian traveller, was born, 1730, at Kinnaird houſe, in the pariſh of Larbert and county of Stirling. His deſcent by both parents was ancient and honourable; and of that deſcent he was, perhaps, too proud. His grandfather was —— Hay, Eſq; of Woodcockdale, in the county of Linlithgow, who, marrying Miſs Bruce, the heireſs of Kinnaird, gave the name of *Bruce* to all his deſcendants.

Perhaps this change of name may have taken place in obedience to the deed by which the eſtate of Kinnaird was ſettled on Mrs Hay's children; but it is a change which, in a country like Scotland, where antiquity of deſcent is highly valued, any man would voluntarily have adopted, who had married the heireſs of ſuch a family. The Bruces of Kinnaird had been in poſſeſſion of that eſtate for three centuries: they were deſcended from a younger ſon of Robert de Bruce, the competitor with Baliol for the crown of Scotland. It would readily occur, that the knowledge of ſuch a deſcent would be beſt preſerved by continuing the name of their great anceſtor; and we have reaſon to believe, that the ſubject of this memoir was not much delighted when put in mind, as he frequently was, that, though the heir of the line, he was not the *male* heir of that branch of the illuſtrious family.

As he was allied to royalty by his father and grandmother, through his mother he was related to ſome of the moſt reſpectable families in the kingdom. She was the daughter of James Graham, Eſq; of Airth, dean of the faculty of advocates, and judge of the high court of admiralty in Scotland, by Marion daughter of James Hamilton, Eſq; of Pencaitland; and to a man of our traveller's turn of mind, there can be no doubt but that it muſt have afforded much ſatisfaction to think, that no family ranks higher in Scotland than thoſe of Bruce, Graham, and Hamilton. In him, however, it was weakneſs to be proud, if indeed he was proud, of family; for the talents beſtowed upon him by nature, or to ſpeak more properly, by nature's God, would have made him great though he had been born on a dunghill. He would indeed have been, in all probability, much greater than he was, had he not been in poſſeſſion of the phantom of birth to gratify much of his ambition; for the facility with which he maſtered every ſtudy in which he engaged, would have carried him quickly to the top of the moſt honourable profeſſion.

Mr Bruce was inſtructed in grammatical learning at the ſchool of Harrow on the Hill, in the county of Middleſex, where he gave the moſt unequivocal proofs of genius, and acquired a very conſiderable knowledge of the Greek and Latin languages. It was cuſtomary with him to perform, not only his own exerciſes, but alſo the exerciſes of ſuch of his companions as were not equal to the taſk themſelves. Among theſe was his maternal uncle, who was frequently indebted to his aſſiſtance, and, on one occaſion, produced a copy of verſes of his compoſition, which excited, not only the applauſe, but the admiration of their maſter. Mr Graham, who was but a few months older than Mr Bruce, had, for ſome tranſgreſſion (we know not what), been puniſhed, as boys in the great ſchools in England are often puniſhed, by having a taſk ſet him, which he ſoon found himſelf unable to perform. His nephew deſired him to be under no uneaſineſs, promiſing to furniſh him with the verſes before the time at which they were to be given in. He was as good as his word; but the maſter of the ſchool ſoon diſcovering that they were not the performance of Mr Graham, exclaimed, that the author of theſe verſes, whoever he was, might apply to himſelf the words of Horace,

——*Sublimi feriam ſidera vertice.*

While Mr Bruce was at Harrow, and for a year or two after he had left it, he was of a very delicate frame, and appeared to his friends to be threatened with a conſumption. The truth is, that he was uncommonly tall for his age, and felt all the feebleneſs of joints and other bodily weakneſſes to which overgrown boys are generally ſubject. His father intended him for the profeſſion of the law; and, upon his return from Harrow, he was entered into the univerſity of Edinburgh, where he went through a regular courſe of ſtudy to fit him for being inrolled in the body of advocates; but for ſome reaſon, which we do not perfectly know, he relinquiſhed the ſtudy of law for the purſuits of trade; and, going to London, entered into partnerſhip with a wine-merchant of the name of Allen, whoſe daughter he married.

That lady falling into a bad ſtate of health, Mr Bruce took her abroad, in hopes that travelling would be attended with beneficial effects; but in theſe he was diſappointed, as ſhe died within a year after her marriage. He was induced, in order to diſpel his grief, to continue his travels; during which his father dying (at Edinburgh, 4th May 1758), the inheritance of his anceſtors devolved upon him, and he returned to Britain. Some of his ſubſequent tranſactions ſhall now be related in his own words.

"Every one will remember that period, ſo glorious to Britain, the latter end of the miniſtry of the late earl of Chatham. I was then returned from a tour through the greateſt part of Europe, particularly thro' the whole of Spain and Portugal, between whom there was then the appearance of an approaching war.

"I was about to retire to a ſmall patrimony I had received from my anceſtors, in order to embrace a life of ſtudy and reflection, nothing more active appearing within my power, when chance threw me unexpectedly into a very ſhort and very deſultory converſation with Lord Chatham.

“ It was a few days after this, that Mr Wood, then under ſecretary of ſtate, my zealous and ſincere friend, informed me that Lord Chatham intended to employ me upon a particular ſervice; that, however, I might go down for a few weeks to my own country to ſettle my affairs, but, by all means, to be ready upon a call. Nothing could be more flattering to me than ſuch an offer, when ſo young; to be thought worthy by Lord Chatham of any employment, was doubly a preference. No time was loſt on my ſide; but juſt after receiving orders to return to London, his lordſhip had gone to Bath, and reſigned his office.

“ This diſappointment, which was the more ſenſible to me that it was the firſt I had met with in public life, was promiſed to be made up to me by Lord Egremont and Mr George Grenville. The former had been long my friend; but unhappily he was then far gone in a lethargic indiſpoſition, which threatened, and did very ſoon put a period to his exiſtence. With Lord Egremont's death my expectations vaniſhed. Further particulars are unneceſſary; but I hope that, at leaſt in part, they remain in that breaſt where they naturally ought to be, and where I ſhall ever think, not to be long forgotten, is to be rewarded.

“ Seven or eight months were paſſed in an expenſive and fruitleſs attendance in London, when Lord Halifax was pleaſed, not only to propoſe, but to plan for me a journey of conſiderable importance, and which was to take up ſeveral years. His lordſhip ſaid, that nothing could be more ignoble than, at ſuch a time of life, at the height of my reading, health, and activity, I ſhould, as it were, turn peaſant, and voluntarily bury myſelf in obſcurity and idleneſs; that though war was now drawing faſt to an end, full as honourable a competition remained among men of ſpirit, which ſhould acquit themſelves beſt in the dangerous line of uſeful adventure and diſcovery.

“ He obſerved, that the coaſt of Barbary, which might be ſaid to be juſt at our door, was yet but partially explored by Dr Shaw, who had only illuſtrated (very judiciouſly indeed) the geographical labours of Sanſon; that neither Dr Shaw nor Sanſon had been, or pretended to be, capable of giving the public any detail of the large and magnificent remains of ruined architecture, which they both vouch to have ſeen in great quantities, and of exquiſite elegance and perfection, all over the country. Such had not been their ſtudy, yet ſuch was really the taſte that was required in the preſent times. He wiſhed, therefore, that I ſhould be the firſt, in the reign juſt now beginning, to ſet an example of making large additions to the royal collection; and he pledged himſelf to be my ſupport and patron, and to make good to me, upon this additional merit, the promiſes which had been held forth to me by former miniſters for other ſervices.

“ The diſcovery of the ſource of the Nile was alſo a ſubject of theſe converſations, but it was always mentioned to me with a kind of diffidence, as if to be expected from a more experienced traveller. Whether this was but another way of exciting me to the attempt I ſhall not ſay; but my heart, in that inſtant, did me juſtice to ſuggeſt, that this too was either to be atchieved by me, or to remain as it had done for theſe laſt 2000 years, a defiance to all travellers, and an opprobrium to geography.

“ Fortune ſeemed to enter into this ſcheme. At the very inſtant, Mr Aſpinwall, very cruelly and ignominiouſly treated by the dey of Algiers, had reſigned his conſulſhip, and Mr Ford a merchant, formerly the dey's acquaintance, was named in his place. Mr Ford was appointed, and, dying a few days after, the conſulſhip became vacant. Lord Halifax preſſed me to accept of this as containing all ſorts of conveniences for making the propoſed expedition.

“ This favourable event finally determined me. I had all my life applied unweariedly, perhaps with more love than talent, to drawing, the practice of mathematics, and eſpecially that part neceſſary to aſtronomy. The tranſit of Venus was at hand. It was certainly known that it would be viſible once at Algiers, and there was great reaſon to expect it might be twice. I had furniſhed myſelf with a large apparatus of inſtruments, the completeſt of their kind, for the obſervation. In the choice of theſe, I had been aſſiſted by my friend Admiral Campbell, and Mr Ruſſel, ſecretary to the Turkey Company: every other neceſſary had been provided in proportion. It was a pleaſure now to know that it was not from a rock or a wood, but from my own houſe at Algiers, I could deliberately take meaſures to place myſelf in the liſt of men of ſcience of all nations, who were then preparing for the ſame ſcientific purpoſe.

“ Thus prepared, I ſet out for Italy, through France; and though it was in time of war, and ſome ſtrong objections had been made to particular paſſports, ſolicited by our government from the French ſecretary of ſtate, Monſieur de Choiſeul moſt obligingly waved all ſuch exceptions with regard to me, and moſt politely aſſured me, in a letter accompanying my paſſport, that thoſe difficulties did not in any ſhape regard me, but that I was perfectly at liberty to paſs through, or remain in, France, with thoſe that accompanied me, without limiting their number, as ſhort or as long a time as ſhould be agreeable to me.

“ On my arrival at Rome, I received orders to proceed to Naples, there to await his majeſty's further commands. Sir Charles Saunders, then with a fleet before Cadiz, had orders to viſit Malta before he returned to England. It was ſaid that the grand maſter of that order had behaved ſo improperly to Mr Harvey (afterwards Lord Briſtol) in the beginning of the war, and ſo partially and unjuſtly between the two nations in the courſe of it, that an explanation on our part was become neceſſary. The grand maſter no ſooner heard of my arrival at Naples, than, gueſſing the errand, he ſent off Chevalier Mazzini to London, where he at once made his peace and his compliments to his majeſty upon his acceſſion to the throne.

“ Nothing remained now but to take poſſeſſion of my conſulſhip. I returned, without loſs of time, to Rome, and from thence to Leghorn, where having embarked on board the Montreal man of war, I proceeded to Algiers.

“ While at Naples, I received from ſlaves, redeemed from the province of Conſtantine, accounts of magnificent ruins they had ſeen while traverſing that country with their maſter the Bey. I ſaw the abſolute neceſſity there was for aſſiſtance, without which it was impoſſible for any one man, however diligent and qualified, to do any thing but bewilder himſelf. All my endeavours, however, had hitherto been unſucceſsful to perſuade any Italian to put himſelf wilfully into the hands of a people conſtantly looked upon by them in no better light than pirates. At laſt Mr Lumiſden, by accident, heard of a young man who was then ſtudying architecture at Rome, a native of Bologna, whoſe name was Luigi Balugani. I can appeal to Mr Lumiſden as to the extent of this perſon's practice and knowledge, and that he knew very little when firſt ſent to me. In the twenty months which he ſtaid with me at Algiers, by aſſiduous application to proper ſubjects under my inſtruction, he became a very conſiderable help to me, and was the only one that ever I made uſe of, or that attended me for a moment, or ever touched one repreſentation of architecture in any part of my journey."

Our traveller, when in Spain, had endeavoured to find acceſs to that immenſe collection of Arabic manuſcripts which were periſhing in the duſt of the eſcurial; but in vain. "All my ſucceſs (ſays he) in Europe terminated in the acquiſition of thoſe few printed Arabic books that I had found in Holland; and theſe were rather biographers than general hiſtorians, and contained little in point of general information. The ſtudy of theſe, however, and of Maracci's Koran, had made me a very tolerable Arab; a great field was opening before me in Africa to complete a collection of manuſcripts, an opportunity which I did not neglect.

"After a year ſpent at Algiers, conſtant converſation with the natives while abroad, and with my manuſcripts within doors, had qualified me to appear in any part of the continent without the help of an interpreter. Ludolf had aſſured his readers, that the knowledge of any oriental language would ſoon enable them to acquire the Ethiopic; and I needed only the ſame number of books to have made my knowledge of that language go hand in hand with my attainments in the Arabic. My immediate proſpect of ſetting out on my journey to the inland parts of Africa, had made me double my diligence; night and day there was no relaxation from theſe ſtudies, although the acquiring any ſingle language had never been with me either an object of time or difficulty."

At Algiers Mr Bruce was detained longer than he expected, in conſequence of a diſpute with the Dey concerning Mediterranean paſſes. This being adjuſted, he proceeded to Mahon, and from Mahon to Carthage. He next viſited Tunis and Tripoli, and travelled over the interior parts of theſe ſtates. At Bengazi, a ſmall town on the Mediterranean, he ſuffered ſhipwreck, and with extreme difficulty ſaved his life, though with the loſs of all his baggage. He afterwards ſailed to the iſles of Rhodes and Cyprus, and proceeding to Aſia Minor, travelled through a conſiderable part of Syria and Paleſtine, viſiting Haſſia, Latikea, Aleppo, and Tripoli; near which laſt city he was again in imminent danger of periſhing in a river. The ruins of Palmyra and Baalbec were next carefully ſurveyed and ſketched by him; and his drawings of theſe places are depoſited in the king's library at Kew; "the moſt magnificent preſent in that line," to uſe his own words, "ever made by a ſubject to his ſovereign."

It is much to be regretted that Mr Bruce publiſhed no particular account of theſe various journeys; from the nature of the places viſited, and the abilities of the man, much curious and uſeful information might have been expected. Some manuſcript accounts of different parts of them are ſaid to have been left by him, but whether in ſuch a ſtate as to be fit for publication, we have not learned.

In theſe various travels ſome years were paſſed; and Mr Bruce now prepared for the grand expedition, the accompliſhment of which had ever been neareſt his heart, the diſcovery of the ſources of the Nile. In the proſecution of that dangerous object, he left Sidon on the 15th of June 1768, and arrived at Alexandria on the 20th of that month. He proceeded from thence to Cairo, where he continued to the 12th of December following, when he embarked on the Nile; and in a very extraordinary boat, called a *canja*, of which he ſays the main-ſail yard was about 200 feet in length, he ſailed up that river as far as Syene, viſiting in the courſe of his voyage the ruins of Thebes, and the place where Memphis once ſtood, now known by the name of *Metrahenny*. Leaving Kenne on the Nile, 16th February 1769, he croſſed the deſert of the Thebaid to Coſſeir on the Red Sea, and arrived at Jidda on the 3d of May. In Arabia Felix he remained, not without making ſeveral excurſions, till the 3d of September, when he ſailed from Loheia, and arrived on the 19th at Maſuah, where he was detained near two months by the treachery and avarice of the Naybe of that place. It was not till the 15th of November that he was allowed to quit Arkeeko, near Maſua; and he arrived on the 15th of February 1770 at Gondar, the capital of Abyſſinia, where he ingratiated himſelf with the moſt conſiderable perſons of both ſexes belonging to the court. This he accompliſhed by being a phyſician in the city, a ſoldier in the field, a courtier everywhere, demeaning himſelf as conſcious that he was not unworthy of being a companion to the firſt of their nobility, and the king's gueſt, which is there a character, as it was with eaſtern nations of old, to which a certain ſort of conſideration is due. "To this I may add (ſays he), that, being in the prime of life, of no ungracious figure, having an accidental knack, which is not a trifle, of putting on the dreſs, and ſpeaking the language eaſily and gracefully, I cultivated, with the utmoſt aſſiduity, the friendſhip of the fair ſex, by the moſt modeſt and reſpectful diſtant attendance and obſequiouſneſs in public, abating juſt as much of that in private as ſuited their humours and inclination;" and jealouſy being a paſſion unknown in Abyſſinia, he thus acquired from the ladies great ſupport at court.

Several months were employed in attendance on the king, and in an unſucceſsful expedition round the lake of Dambea. Towards the end of October Mr Bruce ſet out for the ſources of the Nile; at which long deſired ſpot he arrived on the 14th of November; and his feelings on the accompliſhment of his wiſhes cannot better be expreſſed than in his own words:

"It is eaſier to gueſs than to deſcribe the ſituation of my mind at that moment; ſtanding in that ſpot which had baffled the genius, induſtry, and inquiry, of ancients and moderns for the courſe of near 3000 years. Kings had attempted this diſcovery at the head of armies, and each expedition was diſtinguiſhed from the laſt only by the difference of the numbers which had periſhed, and agreed alone in the diſappointment which had uniformly, and without exception, followed them all. Fame, riches, and honour, had been held out for a ſeries of ages to every individual of thoſe myriads thoſe princes commanded, without having produced one man capable of gratifying the curioſity of his ſovereign, or wiping off this ſtain upon the enterpriſe and abilities of mankind, or adding this deſideratum for the encouragement of geography. Though a mere private Briton, I triumphed here in my own mind over kings and their armies; and every compariſon was leading nearer and nearer to the preſumption, when the place itſelf where I ſtood, the object of my vain glory, ſuggeſted what depreſſed my ſhort-lived triumphs."

If theſe triumphs were ſhort-lived, they were equally ill-founded; for if the ſource of the Nile was ſeen by Mr Bruce, there can be no doubt of its having been likewiſe ſeen by the Portugueſe jeſuits. Of this we have elſewhere brought forward ſufficient proof; and the candid reader, who ſhall take the trouble to compare the extract printed at the bottom of this page (A), with our traveller's account of theſe coy fountains, as it ſtands in his own book or in our article Nile *(Encycl.)*, will be convinced that it was ridiculous in Mr Bruce, and is equally ridiculous in his friends, to pretend that he *diſcovered* what had baffled the genius of inquiry for the courſe of near 3000 years.

It was not, however, the conſciouſneſs of having been anticipated by the jeſuits (for theſe he without ceremony calls a ſet of liars), but the proſpect of danger to be encountered on his return to Europe, that caſt ſuch a damp on his preſent enjoyment. "I was but a few minutes (ſays he) arrived at the ſource of the Nile, through numberleſs dangers and ſufferings, the leaſt of which would have overwhelmed me, but for the continual goodneſs and protection of Providence; I was, however, but then half through my journey, and all thoſe dangers which I had already paſſed awaited me again on my return. I found a deſpondency gaining ground faſt upon me, which blaſted the crown of laurels I had too raſhly woven for myſelf."

When he returned to reſt the night of that diſcovery, repoſe was ſought for in vain. "Melancholy reflections upon my preſent ſtate, the doubtfulneſs of my return in ſafety, were I permitted to make the attempt, and the fears that even this would be refuſed, according to the rule obſerved in Abyſſinia with all travellers who have once entered the kingdom; the conſciouſneſs of the pain that I was then occaſioning to many worthy individuals, expecting daily that information concerning my ſituation which it was not in my power to give them; ſome other thoughts perhaps, ſtill nearer the heart than thoſe, crowded upon my mind, and forbade all approach of ſleep.

"I was, at that very moment, in poſſeſſion of what had for many years been the principal object of my ambition and wiſhes; indifference which, from the uſual infirmity of human nature, follows, at leaſt for a time, complete enjoyment, had taken place of it. The marſh, and the fountains, upon compariſon with the riſe of many of our rivers, became now a trifling object in my ſight. I remembered that magnificent ſcene in my own native country, where the Tweed, Clyde, and Annan, riſe in one hill; three rivers I now thought not inferior to the Nile in beauty, preferable to it in the cultivation of thoſe countries through which they flow; ſuperior, vaſtly ſuperior to it in the virtues and qualities of the inhabitants, and in the beauty of its flocks, crowding its paſtures in peace, without fear of violence from man or beaſt. I had ſeen the riſe of the Rhine and Rhone, and the more magnificent ſources of the Soane; I began, in my ſorrow, to treat the inquiry about the ſource of the Nile as a violent effort of a diſtempered fancy,

'What's Hecuba to him, or he to Hecuba,
'That he ſhould weep for her?'

Grief and deſpondency now rolling upon me like a torrent, relaxed, not refreſhed, by unquiet and imperfect ſleep, I ſtarted from my bed in the utmoſt agony; I went to the door of my tent, every thing was ſtill; the Nile, at whoſe head I ſtood, was not capable either to promote or to interrupt my ſlumbers, but the coolneſs and ſerenity of the night braced my nerves, and chaſed away thoſe phantoms that while in bed had oppreſſed and tormented me.

"It was true that numerous dangers, hardſhips, and ſorrows, had beſet me through this half of my excurſion; but it was ſtill as true, that another Guide, more powerful than my own courage, health, or underſtanding, if any of them can be called man's own, had uniformly

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(A) "In the eaſtern part of this kingdom, on the declivity of a mountain, whoſe deſcent is ſo eaſy that it ſeems a beautiful plain, is that ſource of the Nile which has been ſought after at ſo much expence of labour, and about which ſuch variety of conjectures hath been formed without ſucceſs. This ſpring, or rather theſe two ſprings, are two holes, each about two feet diameter, a ſtone's caſt diſtant from each other. The one is about five feet and an half in depth, at leaſt we could not get our plummet farther, perhaps becauſe it was ſtopped by roots, for the whole place is full of trees: of the other, which is ſomewhat leſs, with a line of ten feet we could find no bottom, and were aſſured by the inhabitants that none ever had been found. It is believed here that theſe ſprings are the vents of a great ſubterraneous lake; and they have this circumſtance to favour their opinion, that the ground is always moiſt, and ſo ſoft that the water boils up under foot as one walks upon it. Such is the ground round about theſe fountains. At a little diſtance to the ſouth is a village named *Guix* (the *Geeſh* of Mr Bruce), through which the way lies to the top of the mountain, whence the traveller diſcovers a vaſt extent of land, which appears like a deep valley, though the mountain riſes ſo imperceptibly, that thoſe who go up or down it are ſcarce ſenſible of any declivity."—*Johnſon's Tranſlation of Father Lobo's Voyage to Abyſſinia*, Chap. X.

The only difference between Lobo's and Bruce's account of theſe fountains worthy of notice is, that the former found but *two*, while the latter found *three* holes; but Bruce ſays expreſsly, that the holes are partly artificial; and Lobo's deſcription of them indicates the ſame thing. It is therefore not improbable that there may now be four or five holes.

formly protected me in all that tedious half. I found my confidence not abated, that ſtill the ſame Guide was able to conduct me to my wiſhed-for home. I immediately reſumed my former fortitude, conſidered the Nile as indeed no more than riſing from ſprings as all other rivers do, but widely differing in this, that it was the palm for 3000 years held out to all the nations of the world as a *detur digniſſimo*, which in my cool hours I had thought was worth the attempting at the riſk of my life, which I had long either reſolved to loſe, or lay this diſcovery a trophy in which I could have no competitor, for the honour of my country, at the feet of my ſovereign, whoſe ſervant I was."

How unworthy is this ranting reflection of the greatneſs of mind which Mr Bruce on other occaſions unqueſtionably diſplayed! Had he indeed been the firſt European who diſcovered thoſe pitiful holes from which the Nile is ſaid to flow, his merit would not have conſiſted in travelling from Gondar to the village Geeſh, and viewing the fountains which are at that village the objects of idolatrous adoration, but in the addreſs with which he contrived to make himſelf the favourite of all the factions which agitated a barbarous and almoſt inhuman nation. In managing thoſe factions, he was indeed great; but he ſeems to have valued himſelf more upon looking at three ſprings, of which it is far from being certain that they are the ſources of the Nile (ſee Nile, *Encycl.*), and of which two had certainly been examined more than a century before he was born, by different miſſionaries from the kingdom of Portugal! This, however, he calls the object of his wiſhes; and having now accompliſhed it, he bent his thoughts on his return to his native country.

He arrived at Gondar on the 19th November 1770; but found, after repeated ſolicitations, that it was by no means an eaſy taſk to obtain permiſſion to quit Abyſſinia. A civil war in the mean time breaking out (no uncommon occurrence in that barbarous country), ſeveral engagements took place between the king's forces and the troops of the rebels, particularly three actions at a place called Serbraxos on the 19th, 20th, and 23d of May 1771. In each of them Mr Bruce acted a conſiderable part, and for his valiant conduct in the ſecond received, as a reward from the king, a chain of gold, of 184 links, each link weighing $3\frac{1}{12}$ dwts. or ſomewhat more than $2\frac{1}{2}$ lbs. troy in all. At Gondar, after theſe engagements, he again preferred the moſt earneſt intreaties to be allowed to return home, intreaties which were long reſiſted; but his health at laſt giving way, from the anxiety of his mind, the king conſented to his departure, on condition of his engaging by oath (b) to return to him in the event of his recovery, with as many of his kindred as he could engage to accompany him.

After a reſidence of nearly two years in that wretched country, Mr Bruce left Gondar on the 16th of December 1771, taking the dangerous way of the deſart of Nubia, in place of the more eaſy road of Maſuah, by which he entered Abyſſinia. He was induced to take this route from his knowledge and former experience of the cruel and ſavage temper of the Naybe of Maſuah. Arriving at Teawa the 21ſt March 1772, he had the misfortune to find the Shekh Fidele of Atbara, the counterpart of the Naybe of Maſuah, in every bad quality; by his intrepidity and prudence, however, and by making good uſe of his foreknowledge of an eclipſe of the moon, which happened on the 17th of April, he was permitted to depart next day, and he arrived at Sennaar on the 29th of the ſame month.

Mr Bruce was detained upwards of four months at that miſerable and inhoſpitable place; the inhabitants of which he deſcribes in theſe expreſſive words: "War and treaſon ſeem to be the only employment of theſe horrid people, whom heaven has ſeparated by almoſt impaſſable deſerts from the reſt of mankind, confining them to an accurſed ſpot, ſeemingly to give them an earneſt in time of the only other worſe which he has reſerved to them for an eternal hereafter." This delay was occaſioned by the villany of thoſe who had undertaken to ſupply him with money; but at laſt, by diſpoſing of 178 links of his gold chain, the well-earned trophy of Serbraxos, he was enabled to make preparation for his dangerous journey though the deſerts of Nubia.

He left Sennaar on the 5th of September, and arrived on the 3d of October at Chendi, which he quitted on the 20th, and travelled through the deſert of Gooz, to which village he came on the 26th of October. On the 9th of November he left Gooz, and entered upon the moſt dreadful and dangerous part of his journey; the perils attending which he has related with a power of pencil not unworthy of the greateſt maſters. All his camels having periſhed, Mr Bruce was under the neceſſity of abandoning his baggage in the deſert, and with the greateſt difficulty reached Aſſouan upon the Nile on the 29th of November.

After ſome days reſt, having procured freſh camels, he returned into the deſert, and recovered his baggage, among which is particularly to be remarked a quadrant (of three feet radius) ſupplied by Louis XV. from the Military Academy at Marſeilles; by means of which noble inſtrument, now depoſited in the muſeum at Kinnaird, Mr Bruce was enabled with preciſion and accuracy to fix the relative ſituations of the ſeveral remote places he viſited.

On the 10th of January 1773, after more than four years abſence, he arrived at Cairo, where, by his manly and generous behaviour, he ſo won the heart of Mahomet Bey, that he obtained a firman, permitting the commanders of Engliſh veſſels belonging to Bombay and Bengal to bring their ſhips and merchandiſe to Suez, a place far preferable in all reſpects to Jidda, to which they were formerly confined. Of this permiſſion, which no European nation could ever before acquire, many Engliſh veſſels have ſince availed themſelves; and it has proved peculiarly uſeful both in public and private diſpatches. Such was the worthy concluſion of his memorable journey through the deſert; a journey which, after many hardſhips and dangers, terminated in obtaining this great national benefit.

At

(b) With regard to this oath, Mr Bruce ſays, that he hopes the difficulty of performing it extinguiſhed the ſin of breaking it; and that, at any rate, it being merely perſonal, his engagement to return ceaſed with the death of the king, of which he received intelligence during his ſtay at Sennaar.

of the narration. Yet there appears upon the whole ſuch an air of manly veracity, and circumſtances are mentioned with a minuteneſs ſo unlike deceit, that theſe doubts are overcome by the general impreſſion of truth, which the whole detail irreſiſtibly faſtens upon the mind. The character of Ras Michael has often ſtruck us, as containing very ſtrong internal evidence of its having been taken from nature; for it is ſuch a character, at once extraordinary and conſiſtent, as neither Mr Bruce, nor perhaps any writer ſince Shakeſpeare, had genius to feign.

The firſt impreſſion of the book being almoſt diſpoſed of, Mr Bruce had ſtipulated with an eminent bookſeller in London for a ſecond edition to be publiſhed, we think in 8vo; and he was buſy in preparing that edition for the preſs when death removed him from this tranſitory ſtage. On the 26th of April 1794 he entertained ſome company at Kinnaird-houſe with his uſual hoſpitality and elegance. About eight o'clock in the evening, when his gueſts were ready to depart, he was handing one of the ladies down ſtairs, when, having reached the ſeventh or eighth ſtep from the bottom, his foot ſlipped, and he fell down headlong. He was taken up ſpeechleſs; his face, particularly the forehead and temples, being ſeverely cut and bruiſed, and the bones of his hands broken. He continued in a ſtate of apparent inſenſibility for eight or nine hours, and expired on Sunday the 27th, in the 64th year of his age.

Mr Bruce's ſecond wife, whom he married on the 20th May 1776, was Mary, eldeſt daughter of Thomas Dundas, Eſq; of Carron-hall, by Lady Janet Maitland, daughter of Charles ſixth Earl of Lauderdale. By that lady, who, after a ſevere and lingering indiſpoſition, died in 1784, he had three children, of whom one ſon and one daughter ſurvive him.

Mr Bruce's perſon was large, his height exceeding ſix feet, his bulk being in proportion to his height; and at the period when he entered on his dangerous expedition, he was equally remarkable for ſtrength and for agility. To thoſe who never beheld him, the engraved medallion in the title pages of the firſt and third volumes of his Travels will convey ſome idea of his features. He excelled in all manly accompliſhments, being trained to exerciſe and fatigue of every kind. He was a hardy, practiſed, and indefatigable ſwimmer; and his long reſidence among the Arabs had given him a more than ordinary facility in managing the horſe. In the uſe of fire arms he was ſo unerring, that in innumerable inſtances he never failed to hit the mark; and his dexterity in handling the ſpear and lance on horſeback was alſo uncommonly great. He was maſter of moſt languages; and was ſo well ſkilled in oriental literature, that he reviſed the New Teſtament in the Ethiopic, Samaritan, Hebrew, and Syriac, making many uſeful notes and remarks on difficult paſſages. He had applied from early youth to mathematics, drawing, and aſtronomy, and had acquired ſome knowledge of phyſic and ſurgery. His memory was aſtoniſhingly retentive, and his mind vigorous. He was dexterous in negociation, a maſter of public buſineſs, and animated with the warmeſt zeal for the glory of his king and country. Such, at leaſt, is *his own* repreſentation of his character; and though an impartial judge would probably make conſiderable abatement for the natural bias of a man drawing his own portrait, yet it cannot be denied, that in perſonal accompliſhments Mr Bruce equalled, if not exceeded, moſt of his contemporaries.

Thus accompliſhed, he could not but be eminently fitted for an attempt ſo full of difficulty and danger as what he called the diſcovery of the ſources of the Nile: no one who peruſes his account of the expedition, can fail to pay an unfeigned tribute of admiration to his intrepidity, manlineſs, and uncommon dexterity, in extricating himſelf out of ſituations the moſt dangerous and alarming, in the courſe of his long and hazardous journey; not to mention his conduct during his reſidence in Abyſſinia, his behaviour at Maſuah, Teawa, and Sennaar, evinces the uncommon vigour of his mind: but it was chiefly during his paſſage through the Nubian deſert that his fortitude, courage, and prudence, appeared to the greateſt advantage. Of his learning and ſagacity, his delineation of the courſe of Solomon's fleet from Tarſhiſh to Ophir, his account of the cauſe of the inundations of the Nile, and his comprehenſive view of the Abyſſinian hiſtory, afford ample proofs. It muſt indeed be confeſſed, that in his account of the inundations of the Nile, as well as in his delineation of the courſe of Solomon's fleet, he has not the merit of originality; but on both theſe occaſions he has ſtated the hypotheſis which he maintains with greater clearneſs, and ſupported it with more plauſible arguments, than any other author whoſe writings have fallen into our hands; and it was ſurely to his honour, that as ſoon as he learned that his hypotheſis reſpecting Ophir and Tarſhiſh had been controverted by Dr Doig of Stirling, he earneſtly courted the acquaintance of that eminent ſcholar.

After his return to his own country, he reſided moſtly at Kinnaird; and till he became corpulent, ſpent much of his time in the various ſports of the field, in which he engaged with great ardour. Though ſtudious in youth, and at all times a ſtranger to intemperance and diſſipation, he read but little in his later years; and ſeemed to find his chief pleaſure in converſation, eſpecially the converſation of well-informed ladies. In his friendſhips he ſometimes appeared to be capricious, attaching himſelf to men in whoſe heads and hearts no other perſon could perceive a charm for a mind like his. Though in his own dealings he was always juſt and honourable, he was too ready to apprehend unfairneſs in others, and to expreſs ſuch apprehenſions with undue warmth. To ſtrangers he was often arrogant, and ſometimes inſolent; but in his own family he was an affectionate huſband, a kind father, an agreeable entertainer, and to his ſervants a maſter perhaps too indulgent. In converſation, as well as in his writings, he embraced every opportunity of expreſſing a deep and lively ſenſe of the care of a ſuperintending Providence, without which he was convinced that there could be no ſafety in human ſtrength or human foreſight. His belief of the Chriſtian religion reſted on the ſureſt grounds; and ſuch was his veneration for the ſacred writings, that for ſome years before his death they ſeemed to occupy all the time which he gave to ſtudy. He read no ſermons, however elegant; and diſſuaded others from ſuch reading. "Read the Bible (ſaid he), and you will ſoon perceive the emptineſs of the moſt applauded ſermons."

BRUNSWICK, a maritime county in Wilmington diſtrict, N. Carolina, containing 3071 inhabitants, of whom 1511 are ſlaves. It is the moſt ſoutherly county of the ſtate, having S. Carolina on the S. W. and bounded by Cape Fear River on the E. Smithville is the ſeat of Juſtice.—*Morſe.*

Brunswick, the chief town in the above county, ſituated on the W. ſide of Cape Fear River; it was formerly the beſt built in the whole ſtate, and carried on the moſt extenſive trade. It lies 30 miles above the capes, about 9 miles N. of Fort Johnſon, 17 S. W. of Wilmington, and was formerly the ſeat of government. In 1780, it was burnt down by the Britiſh, and has now only 3 or 4 houſes and an elegant church in ruins.—*ib.*

Brunswick, a townſhip in Eſſex co. Vermont, on the W. bank of Connecticut River, oppoſite Stratford, in New-Hampſhire.—*ib.*

Brunswick, a city in Middleſex co. New-Jerſey, is ſituated on the S. W. bank of Rariton River, in a low ſituation; the moſt of the houſes being built under a hill which riſes W. of the town. It has between 200 and 300 houſes, and about 2500 inhabitants, one half of whom are Dutch. Queen's College was in this city, but is now extinct as a place of inſtruction. There is a conſiderable inland-trade carried on here. One of the moſt elegant and expenſive bridges in America, has been built over the river oppoſite this city. Brunſwick is 18 miles N. E. of Princetown, 60 N. E. from Philadelphia, and 35 S. W. from New-York. N. lat. 40. 30. W. long. 74. 30.—*ib.*

Brunswick, in Cumberland co. diſtrict of Maine, contains 1387 inhabitants, and lies N. E. of Portland 30 miles, and of Boſton 151. It is in N. lat. 43. 52. on the S. ſide of Merry Meeting Bay, and partly on the S. weſtern ſide of Androſcoggin River. Bowdoin College is to be eſtabliſhed in this town.—*ib.*

Brunswick, the chief town of Glynn co. Georgia, is ſituated at the mouth of Turtle River, where it empties into St Simon's ſound, N. lat. 31. 10. It has a ſafe harbor, and ſufficiently capacious to contain a large fleet. Although there is a bar at the entrance of the harbor, it has depth of water for the largeſt ſhip that ſwims. The town is regularly laid out, but not yet built. From its advantageous ſituation, and from the fertility of the back country, it promiſes to be one of the moſt commercial and flouriſhing places in the ſtate. It lies 19 miles S. of Darien; 60 S. S. W. from Savannah, and 110 S. E. from Louiſville.—*ib.*

Brunswick *Co.* in Virginia, lies between Nottaway and Meherrin rivers, and is about 38 miles long, and 35 broad, and contains 12,827 inhabitants, including 6776 ſlaves.—*ib.*

BUCK-wheat, a ſpecies of Polyganum (ſee that article *Encycl.*), was firſt introduced into Europe about the end of the 15th or the beginning of the 16th century. According to ſome botaniſts, who lived at that period, its native country is the northern parts of Aſia, whence it was brought to Germany and France, where, about the year 1587, it was the common food of the poor.

A new ſpecies of this grain, or, to ſpeak perhaps more properly, a variety of this ſpecies, has been for ſome time known under the name of *Siberian* buck-wheat, which appears to have conſiderable advantages over the former. It was ſent from Tartary to St Peterſburgh by the German botaniſts, who travelled thro' that country in the beginning of the preſent century; and it has thence been diſperſed over all Europe. Linnæus received the firſt ſeeds of it in 1737 from Garber the botaniſt, and deſcribed the plant in his *Hortus Cliffertionus*. After this it was mentioned by Ammann in 1739: but it muſt have been earlier known in Germany; for in 1733 it was growing in the garden of Dr Ehrhart at Memmingen. In Siberia this plant ſows itſelf for four or five years by the grains that drop; but at the end of that period the land becomes ſo full of tares that it is choaked, and muſt be ſown afreſh. Even in the economical gardens of Germany, it is propagated in the ſame manner; and in that country it is in ſome places found growing wild, though it is nowhere cultivated in the neighbourhood. In the United States it is cultivated very extenſively and is found a valuable article, whether for manure, for ſheltering young clover, or for a crop of grain, which is much uſed for bread and alſo for feeding cattle.

BUCKS *Co.* in Pennſylvania, lies S. W. from Philadelphia. It is ſeparated from Jerſey by Delaware River, on the S. E. and N. E. and has Northampton co. on the N. W. It contains 25,401 inhabitants, including 114 ſlaves. Bucks is a well cultivated county, containing 411,900 acres of land, and is divided into 27 townſhips, the chief of which is Newtown. It abounds with lime ſtone, and in ſome places are found iron and lead ore. There is a remarkable hill in the N. end of the county called Haycock, in the townſhip of the ſame name. It is 15 miles in circumference, having a gradual aſcent, and from its ſummit is a delightful proſpect. The waters of Tohickon Creek waſh it on all ſides except the weſt.—*Morſe.*

BULAM, or Bulama, as it is more uſually called, forms part of the Archipelago, or cluſter of iſlands, lying on the weſtern or windward coaſt of Africa, and known by the name of the *Biſſaos* or *Biſſagos*, which are ſuppoſed to have been celebrated by the ancients under the appellation of the *Heſperides*. It is ſituated at the mouth of the Rio Grande, in 11° N. Lat. and 15° W. Long. from the meridian of London; and is between ſeventeen and eighteen leagues long, and from four to five broad.

This iſland has become an intereſting object to the inhabitants of Great Britain, in conſequence of its having been purchaſed in the year 1792 by a ſociety inſtituted for the ſame humane purpoſes with thoſe which gave riſe to the Sierra-Leone company (ſee *Sierra-Leone*, Encycl.). The Bulam aſſociation was formed towards the latter end of the year 1791; and they were induced to pitch upon that iſland as the moſt eligible tract for their intended colony, in conſequence of the flattering deſcription given of its climate, ſoil, and harbours, by M. Brue, formerly director-general of the French African companies.

The gentlemen originally appointed as truſtees for managing the concerns of the aſſociation at home were, *Paul Le Meſurier*, M. P.; *James Kirkpatrick*, Eſq; *George Hartwell*, Eſq; *Moſes Ximenes*, Eſq; *Sir John Riggs Miller*, Bart. and *David Scott*, Eſq; M. P; and for eſtabliſhing the colony, and conducting the affairs of the ſociety abroad, the following gentlemen were nominated, viz. *Meſſrs H. H. Dalrymple*, *John Young*, *Sir William Halton*, Bart. *John King*, *Philip Beaver*, *Peter Clutterbuck*, Bulama.

Clutterbuck, *Nicholas Bayly*, *Francis Brodie*, *Charles Drake*, *John Paiba*, *Richard Handcorne*, *Robert Dobbins*, and *Iſaac Ximenes*.

A ſum of L.9000 being quickly ſubſcribed for the eſtabliſhment of the intended colony, this committee ſailed from Spithead in three ſhips on the 11th of April 1792; and landing in due time at Bulama, they purchaſed that iſland from the kings of Canabac, who claimed it as their property. They purchaſed likewiſe from the kings of Ghinala the neighbouring iſland Arcas, and the adjacent land on the continent; and theſe ſeveral purchaſes being taken poſſeſſion of in the uſual form, a body of ſettlers, conſiſting of 49 men, 13 women, and 25 children, were left at Bulama under the ſuperintendance of Mr Beaver, with a temporary ſupply of proviſions, ſtores, plantation-tools, and merchandiſe, for trading with the neighbouring natives. It is from the diſpatches of theſe ſettlers, after having lived ſome time in Bulama, that the following account of the iſland was drawn up by Mr Johanſen.

“ The climate, on the whole, may be deemed ſalubrious, and will become more ſo in proportion to the increaſe of cultivation. The mornings and evenings are temperate and pleaſant; the middle of the day is hot, but the fine ſea-breeze which then ſets in tends greatly to cool and refreſh the air. The heat of the ſun is not either ſo exceſſive or intolerable as has been generally ſuppoſed; indeed nature has moſt admirably adapted our mechanical and phyſical qualities to the exigencies of different regions; and man, who is the inhabitant of every climate, may, in ſome meaſure, render himſelf indigenous to every ſoil. Here the only danger ariſes from too ſudden an expoſure to the operation of the vertical rays of the ſun, or an exceſs of labour; both of which the firſt ſettlers ought moſt ſtudiouſly to avoid.

“ It appears from Mr Beaver's obſervations at noon, between the 20th of July 1792, and the 28th of April 1793, that the thermometer, when loweſt, was at 74; the medium heat 85; and that it never exceeded 96, except at one time when it roſe to 100, during a calm that occurred in the interval between the north-eaſt breeze in the morning and the ſouth-weſt in the evening of the 19th of February 1793. The difference between the heat of noon and that of the morning and evening is from 20 to 30 degrees. On the 23d of October 1792, hail of the ſize of a pin's head fell during two minutes, although not a cloud was to be ſeen during this phenomenon. The mercury in the thermometer then ſtood at 85; the wind was at north-eaſt in the morning and ſouth-weſt in the evening.

“ Immediately after ſun ſet a dew conſtantly begins to fall, which induces ſome to light a fire in their houſes; they at the ſame time put on warmer clothing. There is little or no twilight; and night and day are nearly equal: the earth has therefore time to cool during twelve hours abſence of the ſun.

“ None of thoſe terrible and deſtructive hurricanes ſo frequently experienced in the Weſt Indies are to be met with here. The *tornadoes*, which ariſe chiefly from the eaſtern point of the compaſs, are but of ſhort duration, ſeldom laſting above an hour, and may be readily foreſeen ſome time previouſly to their commencement. They occur at the beginning and cloſe of the wet ſeaſon, and are highly beneficial, as they purify the air, and diſpel the noxious vapours with which it would otherwiſe abound.

“ The rains ſet in about the latter end of May or the beginning of June, and diſcontinue in October or November. They do not fall every day, for there is often a conſiderable interval of clear weather, during which the atmoſphere is beautifully ſerene; the ſhowers in the firſt and laſt month occur but ſeldom, and are far from being violent; while on the other hand, they ſometimes reſemble torrents, more eſpecially towards the middle of the ſeaſon. During the whole of this period, Europeans ſhould, if poſſible, confine themſelves to their habitations, as the rains prove injurious to health, more eſpecially if thoſe expoſed to them neglect to wipe their bodies dry, and to change their clothes immediately on their return home. It is deemed prudent alſo not to dig the earth until the expiration of a month after the return of fair weather, as this is conſidered to be unhealthy.

“ During the continuance of the dry ſeaſon, a dew falls during the night, in ſufficient quantity to anſwer all the purpoſes of vegetation.

“ Every ſtranger is generally here, as well as in the Weſt Indies, ſubject to a fever or *ſeaſoning*, on his arrival. This is not infectious; it proceeds perhaps from an increaſed perſpiration and a ſudden extenſion of the pores of the human body, in conſequence of the heat, by which means it is rendered more liable to imbibe the abundant exhalations that ariſe from the animal, vegetable, and mineral kingdoms; but even this, ſlight as it is, might doubtleſs be avoided by means of a proper regimen, and a ſhort ſecluſion from the full action of the open air, more eſpecially at noon, and during the evening, until the climate has been rendered familiar.

“ Bulama is admirably adapted for all the purpoſes of an extenſive commerce, being not only happily ſituated at the mouth of the Rio Grande, but in the vicinity of ſeveral other navigable rivers; ſo that a trade with the internal parts of Africa is thereby greatly facilitated. The landing is remarkably eaſy and ſafe, there being no ſurge; the ebb and flow is regular, and there is an increaſe of 16 feet of water at ſpring tide. The bay oppoſite the Great Bulama is adorned with a number of iſlands, covered with trees, and forms a moſt excellent harbour, ſufficiently capacious to contain the whole navy of Great Britain, which might ride there in ſafety. The ſettlement in general is well ſupplied with water. A number of ſprings have been lately diſcovered in different places; and beſides a draw-well in the fort, which was erected for the defence of the colony, there is a ſmall ſtream, which runs into Elewſis Bay, near the new ſettlement called Heſper Elewſis: this is admirably ſituated for the ſupply of ſhipping.

“ The iſland is beautifully ſurrounded, and interſperſed with woods: lofty fruit and foreſt trees, moſtly free from underwood and brambles, form a verdant belt, in ſome places two or three miles broad, which entirely encircles it, in ſuch a manner as to repreſent a plantation artificially formed around a park. Within this the fields are regularly divided by trees, ſo as to reſemble the hedge rows in England. The beach has in ſome places the appearance of gravel walks; it is fringed with mangrove trees, which forming a line with the high-water mark, dip their branches into the ſea, and thus afford nouriſhment to the oyſters that often adhere to their extremities.

Several parts of Bulama have been occaſionally cultivated by the neighbouring blacks, though they did not conſtantly reſide on it.

“ The land in general riſes gradually towards the middle of the iſland, where the higheſt ſpot is from 60 to 100 feet above the level of the ſea. The ſmall hill on which the fort is ſituated is nearly of the ſame altitude.

“ The ſoil is abundantly rich and deep; ſtones do not here impede the labours of the farmer; and indeed none have hitherto been diſcovered, but a ſmall ſort, reſembling pieces of ore, which are to be met with on the ſhore. There are many *ſavannahs* or natural meadows, ſo extenſive that the eye can ſcarcely deſcry their boundaries. Theſe are admirably adapted for the rearing of ſtock and feeding of cattle of every kind.

“ Cotton, indigo, rice, and coffee, grow ſpontaneouſly on this coaſt; the ſugar-cane is indigenous to many parts of Africa, and might be cultivated here by the labour of freemen, in equal perfection, and to much greater advantage, than in the exhauſted iſlands of the Weſt Indies. All kinds of tropical productions, ſuch as pine-apples, limes, oranges, grapes, plums, caſſada, guava, Indian wheat, the papaw, water-melon, muſk-melon, the pumkin, tamarind, banana, and numbers of other delicious fruits, alſo flouriſh here. The adjoining territories produce many valuable ſorts of ſpices, gums, and materials for dying; all of which, it is but fair to ſuppoſe, might be readily cultivated in a kindred climate and a congenial ſoil.

“ The neighbouring ſeas abound with a variety of fiſh, highly agreeable to the palate. The lion, tyger, jackall, &c. are natives of the continent; but in Bulama no animals have been diſcovered, the wolf, ſome buffaloes, a few elephants, and a ſpecies of the deer excepted.

“ The woods abound with doves, guinea fowls, and a variety of birds, celebrated for the beauty of their plumage.

“ The natives of this part of Africa, like all ſavages, are entirely under the dominion of their paſſions: hence the violence of their attachment to their friends, and the exceſs of their reſentment againſt their enemies. Their notions of property are very obſcure and confuſed: they have no idea of any right ariſing from occupancy or improvement. What they want, they either receive or take wherever they may happen to meet with it, and they permit others to do the ſame. They have been taught by experience, that the Europeans will not agree to this: againſt them therefore they employ every artifice that it is in the power of cunning to ſuggeſt.

“ The coloniſts need not fear any attack on the part of the negroes, provided their own conduct be juſt and peaceable: for Mr Beaver, who was indeed admirably calculated by nature and habit for the ſtation he occupied, could inſure both ſafety and reſpect when the ſettlers under him were reduced to four white men, although the neighbouring nations knew that he was in poſſeſſion of commodities, for the acquiſition of which many of them had become day-labourers. He often kept from twenty to forty gromittos, or black cultivators in pay, at that very period, at about four or five bars (A) each per month. Theſe are eaſy to be procured, to almoſt any number that can poſſibly be wanted.

“ Until a ſufficient quantity of ſtock and proviſions can be raiſed in the company's ſettlements, the adjacent iſlands will furniſh abundance of cattle, hogs, fowls, &c. at a very cheap rate. A horſe may be purchaſed at Goree for 1 l. 10 s. a bullock may be had from 12 s. to 18 s. ſterling: proviſions of all kinds are equally reaſonable. Honey is alſo to be procured in great plenty, and bees wax may be rendered an advantageous object of commercial ſpeculation.

“ In ſhort, the acquiſition of Bulama, Arcas, and the adjacent territories, preſents the faireſt opportunity of furniſhing Europe with many valuable articles that have hitherto been brought from more remote countries, with much greater hazard, and at an increaſed expence. The intercourſe with England is eaſy, ſafe, and expeditious; for the voyage may be performed in the ſpace of three or four weeks: and by the terms of the firſt ſubſcription, a ſettler on Bulama might purchaſe 500 acres of land for L. 30 ſterling; by the terms of the ſecond, which we ſuppoſe are the terms at preſent, he might purchaſe on the iſlands of Bulama and Arcas, or on that part of the adjacent coaſt which was ceded to the ſociety by the kings of Ghinala, 200 acres for L. 50 ſterling.

“ The colonization of Africa opens a noble and extenſive field to nations and to individuals. To people thoſe fertile territories, deſpoiled of their inhabitants by the ſlave-trade; to rear the productions of the climes between the tropics, by the aſſiſtance of free men; to give ample ſcope to the induſtry and exertions of thoſe who may be inclined to remove from Great Britain; and to extend the commerce and the manufactures of our native country—theſe are ſubjects which have excited the attention of the Bulama aſſociation, and now claim the aſſiſtance of the ingenious, the ſupport of the rich, and the concurrence and good wiſhes of all.

BUNCOMB, the largeſt and moſt weſtern county of North Carolina, and perhaps the moſt mountainous and hilly in the United States. It is in Morgan diſtrict, bounded W. by the ſtate of Tenneſſee; and S. by the ſtate of South Carolina. The Blue Ridge paſſes through Buncomb, and gives riſe to many large rivers, as Catabaw, Wateree, Broad River and Pacolet.—*Morse.*

BUNTING, is a bird which has been deſcribed under its generic name Emberiza *(Encycl.)*; but there is one ſpecies, the *orange-ſhouldered bunting* of Latham, of which M. Vaillant relates ſome particulars certainly not unworthy of notice in this place.

“ The female of this beautiful bird (ſays he) has the ſimple colours of the ſky lark, and a ſhort horizontal tail, like that of almoſt all other birds: the male, on the contrary, is wholly black except at the ſhoulder of the wing, where there is a large red patch; and his tail is long, ample, and vertical, like that of the common cock. But this brilliant plumage and fine vertical tail ſubſiſt only during the ſeaſon of love, which continues ſix

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(A) A bar is about the value of three ſhillings and ſixpence.

ſix months. This period over, he lays aſide his ſplendid habiliments, and aſſumes the more modeſt dreſs of his mate. The moſt extraordinary circumſtance is, that the vertical tail alſo changes to a horizontal one, and the male ſo exactly reſembles the female, that it is not poſſible to diſtinguiſh them from each other.

" The female has her turn. When ſhe reaches a certain age, and has loſt the faculty of propagating the ſpecies, ſhe clothes herſelf for the remainder of her days in the garb which the male had temporarily aſſumed; her tail, like his at that period, grows long, and, like his alſo, from horizontal becomes vertical.

" The birds of this ſpecies aſſociate together, live in a ſort of republic, and build their neſts near to each other. The ſociety uſually conſiſts of about fourſcore females; but whether, by a particular law of nature, more females are produced than males, or for any other reaſon of which I am ignorant, there are never more than twelve or fifteen males to this number of females, who have them in common."

According to our author, this tranſmutation is by no means confined to this particular ſpecies of bunting. Many females of the feathered creation, when they grow ſo old as to ceaſe laying eggs, aſſume the more ſplendid colours of the male, which they retain during the remainder of their lives. This fact is ſtrikingly perceptible in thoſe ſpecies in which the male and female very much differ in colour, as the golden pheaſant of China, for inſtance. In ſome ſpecies, and thoſe not a few, the male alone regularly changes his colour, and aſſumes once in a year the plumage of the female; ſo that at a certain period all the birds of that ſpecies appear females. " I have in my poſſeſſion (ſays our author) ſpecimens of more than fifty of thoſe changing ſpecies, in all their tranſitions from one hue to another; and the change is ſometimes ſo great, that a perſon would ſuppoſe himſelf to ſee individuals totally different. A cloſet-naturaliſt, for inſtance, ſhewed me four birds as ſo many different ſpecies, and even as not belonging to the ſame genus, with which I was well acquainted, and which I knew to be the ſame bird, only of different ages."

Such changes as theſe, could they be proved to take place occaſionally among domeſtic fowls, would in ſome meaſure account for ſtrange ſtories of cocks laying eggs, which we have heard related by perſons whoſe general veracity was never queſtioned.

BURKE (Edmund), was born in the city of Dublin on the 1ſt of January 1730. His father was an attorney of conſiderable knowledge in his profeſſion, and of extenſive practice; and the family from which he ſprung was ancient and honourable. He received the rudiments of his claſſical education under Abraham Shackleton, a Quaker, who kept a private ſchool or academy, as it has been called, at Bellytore, near Carlow, and is ſaid to have been a very ſkilful and ſucceſsful teacher.

Under the tuition of this maſter Burke devoted himſelf with great ardour, induſtry, and perſeverance, to his ſtudies; and manifeſted, even from his boyiſh days, a diſtinguiſhed ſuperiority over his contemporaries. He was the pride of his preceptor, who prognoſticated every thing great from his genius, and who was, in return, treated by his illuſtrious pupil, for forty years, with reſpect and gratitude.

From ſchool Burke was ſent to Trinity-college, Dublin, where it was aſſerted by Goldſmith and others his contemporaries, that he diſplayed no particular eminence in the performance of his exerciſes. Like Swift, he deſpiſed the logic of the ſchools; and like him too, he devoted his time and his talents to more uſeful purſuits. Johnſon, though proud of being an Oxonian, did not much employ himſelf in academical exerciſes; and Dryden and Milton, who ſtudied at Cambridge, were neither of them ambitious of college diſtinctions. Let not, however, the example of a Burke, a Johnſon, a Dryden, or a Milton, ſeduce into by-paths the ordinary ſtudent; for though great genius either finds or makes its own way, common minds muſt be content to purſue the beaten track. Shakeſpeare, with very little learning, was the greateſt dramatic poet that ever wrote; but how abſurd would it be to infer from this fact, that every illiterate man may excel in dramatic poetry?

Whilſt at college Burke applied himſelf with ſufficient diligence to thoſe branches of mathematical and phyſical ſcience which are moſt ſubſervient to the purpoſes of life; and though he neglected the ſyllogiſtic logic of Ariſtotle, he cultivated the method of induction pointed out by Bacon. Pneumatology, likewiſe, and ethics, occupied a conſiderable portion of his attention; and whilſt attending to the acquiſition of knowledge, he did not neglect the means of communicating it. He ſtudied rhetoric and the art of compoſition, as well as logic, phyſics, hiſtory, and moral philoſophy; and had at an early period of his life, ſays Dr Biſſet, planned a confutation of the metaphyſical theories of Berkeley and Hume.

For ſuch a taſk as this, we do not think that nature intended him. Through the ever-active mind of Burke ideas ſeem to have flowed with too great rapidity to permit him to give that patient attention to minute diſtinctions, without which it is vain to attempt a confutation of the ſubtleties of Berkeley and Hume. The ableſt antagoniſt of theſe two philoſophers was remarkable for patient thinking, and even *apparent* ſlowneſs of apprehenſion; and we have not a doubt, but that if he had poſſeſſed the rapidity of thought which characteriſed Burke, his confutation of Hume and Berkeley would have been far from concluſive: It might have been equal to the *Eſſay on the Nature and Immutability of Truth*, but would not have been what we find it in *The Inquiry into the Human Mind on the Principles of Common Senſe*, and in *The Eſſays on the Intellectual and Active Powers of Man*.

A taſk much better ſuited to Burke's talents than the writing of metaphyſical diſquiſitions on the ſubſtratum of body, preſented itſelf to him in the year 1749, and a taſk which was likewiſe more immediately uſeful. At that period one Lucas, a democratic apothecary, wrote a number of very daring papers againſt government, and acquired by them as great popularity at Dublin as Mr Wilkes afterwards obtained by his North Briton in London. Burke, though a boy, perceived, almoſt intuitively, the pernicious tendency of ſuch levelling doctrines, and reſolved to counteract it. He wrote ſeveral eſſays in the ſtyle of Lucas, imitating it ſo exactly as to deceive the public; purſuing his principles to conſequences neceſſarily reſulting from them, and ſhewing at the ſame time their abſurdity and their danger. Thus was his firſt literary effort, like his laſt, calculated to guard his country againſt anarchical innovations.

Whilſt employed in treaſuring up knowledge, which at a future period was to command the admiration of liſtening ſenates, he did not neglect the means neceſſary to render himſelf agreeable in the varied intercourſe of private life. To the learning of a ſcholar he added the manners of a gentleman. His company was ſought among the gay and the faſhionable, for his pleaſing converſation and eaſy deportment; as much as among the learned, for the force and brilliancy of his genius, and the extent and depth of his knowledge. But though the object of very general regard in his native country, he had hardly any proſpect of obtaining in it an independent ſettlement. He therefore applied, ſome time after the publication of his letters expoſing the doctrines of Lucas, for the profeſſorſhip of logic, which had then become vacant in the univerſity of Glaſgow: but whether that application was made too late, or that the univerſity was unwilling to receive a ſtranger, certain it is that the vacant chair was filled by another, and that Burke was diſappointed of an office in which he was eminently qualified to excel. For many years very little attention has been paid in the univerſities of Scotland, perhaps even too little, to the Ariſtotelian logic; and the profeſſors, inſtead of employing their time in the analyſing of ſyllogiſms, deliver lectures on rhetoric and the principles of compoſition—lectures which no man was more capable of giving than the unſucceſsful candidate for the profeſſorſhip in Glaſgow.

Diſappointment of early views has frequently been the means of future advancement. Had Johnſon become maſter of the Staffordſhire ſchool, talents might have been conſumed in the tuition of boys which Providence formed for the inſtruction of men; and had Burke obtained the profeſſorſhip of logic in Glaſgow, he would have been the moſt eloquent lecturer in that univerſity, inſtead of the moſt brilliant ſpeaker in the Britiſh ſenate: but whether his talents might not have been as uſefully employed in the univerſity as in the ſenate, may perhaps be a queſtion, though there can be no queſtion whether they would have inveſted himſelf with an equal blaze of ſplendour.

Diſappointed in Glaſgow, he went to London, where he immediately entered himſelf of the Temple; and as there is reaſon to believe that he was in ſtraitened circumſtances, he ſubmitted to the drudgery of regularly writing for daily, weekly, and monthly publications, eſſays on general literature and particular politics. The profits ariſing from ſuch writings were at firſt ſmall; but they were ſo neceſſary to their author, that the intenſe application which they required gradually impaired his health, till at laſt a dangerous illneſs enſued, when he reſorted for medical advice to Dr Nugent, a phyſician whoſe ſkill in his profeſſion was equalled only by the benevolence of his heart. The Doctor, conſidering that the noiſe, and various diſturbances incidental to chambers, muſt retard the recovery of his patient, furniſhed him with apartments in his own houſe, where the attention of every member of the family contributed more than medicines to the reſtoration of his health. It was during this period that the amiable manners of Miſs Nugent, the Doctor's daughter, made a deep impreſſion on the heart of Burke; and as ſhe could not be inſenſible to ſuch merit as his, they felt for each other a mutual attachment, and were married ſoon after his recovery.

Hitherto his mental powers and acquirements were known in their full extent only to his friends and more intimate companions; but they were now made public in his firſt acknowledged work, intitled, *A Vindication of Natural Society*. The object of this performance was to expoſe the dangerous tendency of Lord Bolingbroke's philoſophy. By the admirers of that nobleman his principles were deemed inimical only to revealed religion and national churches, which they would have been glad to ſee overturned, provided our civil eſtabliſhment had been preſerved; and to the civil eſtabliſhment they perceived no danger in the writings of the author of *The Patriot King*. Mr Burke thought very differently; and endeavoured to convince them, that if his Lordſhip's philoſophy ſhould become general, it would ultimately deſtroy their rank, their conſequence, and their property, and involve the church and ſtate in one common ruin. In his ironical attack upon artificial ſociety, he makes uſe of the ſame common-place mode of unfair reaſoning which his noble antagoniſt had employed againſt religion and religious eſtabliſhments. He argues, from the incidental abuſes of political ſociety, that political ſociety muſt itſelf be evil; he goes over every form of civil polity, pointing out its defects in the moſt forcible language; and, in perfect imitation of the ſceptical philoſophy, he pulls them all down, one after another, without propoſing any thing in their ſtead. So complete is the irony, that to many not acquainted with ſuch diſquiſitions, he would appear to be ſeriouſly inveighing againſt civil government: and we have actually heard ſome of the advocates for modern innovation mention this work as a proof how different Mr Burke's opinions in politics once were from what they appear to have been when he wrote his *Reflections on the French Revolution*.

The truth, however, is, that there is no inconſiſtency between *The Vindication of Natural Society* and the lateſt publications of its illuſtrious author. At the period when that work was publiſhed, infidelity had infected only the higher orders of men, and ſuch of the lower as had got the rudiments of a liberal education. Of theſe we believe a ſingle individual was not then to be found, who ſuppoſed that ſociety could ſubſiſt both without government and without religion; and therefore whilſt they laboured to overturn the church, and to prove that Chriſtianity itſelf is an impoſture, they all pretended to be zealouſly attached to the civil government as eſtabliſhed in king, lords, and commons. Except the clergy of the eſtabliſhed church, there was no order of men whom they indiſcriminately reviled. Hence it was that not Burke only, but Warburton, and almoſt every other opponent of Lord Bolingbroke, began their defences of revelation, by ſhewing the indiſſoluble connection between the civil and eccleſiaſtical eſtabliſhments, and all the difference was, that he did, through the medium of the moſt refined irony, the very ſame thing which they had done by ſerious reaſoning.

Soon after his *Vindication of Natural Society*, Burke publiſhed *A Philoſophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful*; a work which ſoon made its author univerſally known and admired, and which has been ſtudied by every Engliſh reader of taſte.

It is therefore needleſs for us to hazard any opinion either of its general merit or its particular defects. In one of the literary journals of that day, Mr Murphy urged objections againſt ſome of its fundamental principles, which, in our opinion, it would be very difficult to anſwer; whilſt Johnſon, who was certainly a ſevere judge, conſidered it as a model of philoſophical criticiſm. "We have (ſaid he) an example of true criticiſm in Burke's Eſſay on the Sublime and Beautiful. There is no great merit in ſhewing how many plays have ghoſts in them, or how this ghoſt is better than that; you muſt ſhew how terror is impreſſed on the mind."

In conſequence of this manifeſtation of Burke's intellectual powers, his acquaintance was courted by men of diſtinguiſhed talents, and, among others, by Johnſon and Sir Joſhua Reynolds. The literary club, which has been mentioned *(Encycl.)* in the life of Johnson, was inſtituted for their entertainment and inſtruction, and conſiſted at firſt of Johnſon, Burke, Reynolds, Goldſmith, Dr Nugent, Mr Topham, Beauclerc, Sir John Hawkins, Mr Chamier, and Mr Bennet Langton, who were all men of letters and general information, though far above the reſt ſtood Burke and Johnſon. Of Burke indeed, Johnſon declared, upon all occaſions, that he was the greateſt man living; whilſt Burke, on a very ſolemn occaſion, ſaid of Johnſon, "He has made a chaſm, which not only nothing can fill up, but which nothing has a tendency to fill up. Johnſon is dead. Let us go to the next beſt—There is nobody—No man can be ſaid to put you in mind of Johnſon." Nor was the opinion which theſe two illuſtrious men held of each other's powers peculiar to themſelves alone: all the members of the club obſerved, that, in colloquial talents, they were nearly matched, and that Johnſon never diſcourſed with ſuch animation and energy as when his powers were called forth by thoſe of Burke.

Some years before the inſtitution of this club, Burke, who had devoted much of his time to the ſtudy of hiſtory and politics, propoſed to Mr Dodſley, an eminent bookſeller, a plan of an Annual Register of the civil, political, and literary tranſactions of the times; and the propoſal being acceded to, the work was begun and carried on for many years, either by Burke himſelf, or under his immediate inſpection. It bears indeed internal marks of his genius, his learning, and his candour, being by much the moſt elegant and impartial periodical hiſtory which has perhaps appeared in any age or nation. Even when the heat of oppoſition made him, in his ſpeeches, ſometimes miſrepreſent the conduct of adminiſtration, the Annual Regiſter, under his management, continued to render juſtice to all parties.

He ſtill continued to write occaſionally political eſſays for other publications than the Annual Regiſter; and ſome of theſe eſſays in the *Public Advertiſer* having attracted the notice of the Marquis of Rockingham, that nobleman ſought the acquaintance of their author. It was in the year 1765 that the firſt interview took place between them; and the Marquis, who was then at the head of the treaſury, offering to make Burke his own ſecretary, the offer was readily accepted. On this occaſion he gave a remarkable proof of diſintereſtedneſs and delicate integrity. Through the influence of Mr Hamilton, known by the appellation of *Single-Speech* Hamilton, and long ſuſpected to be the author of *Junius's Letters*, he had ſome time before obtained a penſion of L. 300 a year on the Iriſh eſtabliſhment; but this penſion he now thought it incumbent upon him to reſign, becauſe he had connected himſelf with a party oppoſite in many things to the party whoſe meaſures were ſupported by his friend.

During the Rockingham adminiſtration he was choſen member of parliament for the borough of Wendover in the county of Bucks; and he prepared himſelf for becoming a public ſpeaker, by ſtudying, ſtill more cloſely than he had yet done, hiſtory, poetry, and philoſophy; and by ſtoring his mind with facts, images, reaſonings, and ſentiments. He paid great attention likewiſe to parliamentary uſage; and was at much pains to become acquainted with old records, patents, and precedents, ſo as to render himſelf complete maſter of the buſineſs of office. That he might communicate without embarraſſment the knowledge which he had thus laboriouſly acquired, he frequented, with many other men of eminence, the Robin Hood Society, where he practiſed the replies and contentions of eloquence; and to acquire a graceful action, with the proper management of his voice, he was a very diligent obſerver of Garric in Drury-Lane theatre. He procured his ſeat in 1765, and in the enſuing ſeſſion delivered his maiden ſpeech; which was ſuch a diſplay of eloquence as excited the admiration of the Houſe, and drew very high praiſe from its moſt diſtinguiſhed member Mr Pitt, afterwards Earl of Chatham.

The principal objects which engaged the attention of the Rockingham adminiſtration were the ferments in America, which was then in a ſtate little ſhort of rebellion, on account of the famous ſtamp-act. Parliament was divided in opinion reſpecting that meaſure. Whilſt Mr Grenville and his party (under whoſe auſpices the ſtamp-act had paſſed into a law) were for enforcing obedience to it by coercive meaſures, Mr Pitt and his followers denied that the parliament of Great Britain had a right to tax the Americans; and the marquis of Rockingham, who was hardly able to carry any meaſure in oppoſition to both theſe parties, had to conſider, on this occaſion, whoſe ſentiments he would adopt. By the advice, it is ſaid of Mr Burke, he choſe a middle courſe between the two oppoſite extremes. To gratify the Americans, he repealed the ſtamp-act; and to vindicate the honour of Britain, he got a law paſſed declaratory of her right to legiſlate for America in taxation as in every other caſe.

This meaſure, whoever was its author, was certainly not the offspring either of wiſdom or vigour. If the mother country had a right to legiſlate in all caſes for America, obedience to the ſtamp-act ſhould certainly have been enforced; and the miniſtry which relinquiſhed an acknowledged right, to gratify the diſpoſition of diſtant colonies, was conſidered as unfit to guide the helm of a great empire. Lord Rockingham and his friends were accordingly diſmiſſed from office; and a new adminiſtration was formed under the auſpices of Mr Pitt, now created Earl of Chatham.

Burke, in the mean time, wrote in defence of the party with which he was connected; and aſſumed great credit to it for compoſing the diſtractions of the Britiſh empire by the repeal of the American ſtamp-act, whilſt the conſtitutional ſuperiority of Great Britain was preſerved by the act for ſecuring the dependence of the colonies. After defending his friends, he proceeds to attack thoſe who had ſucceeded them in office. Of Lord Chatham he ſays—“ He has once more deigned to take the reins of government into his own hand, and will, no doubt, drive with his wonted ſpeed, and raiſe a deal of duſt around him. His horſes are all matched to his mind; but as ſome of them are young and ſkittiſh, it is ſaid he has adopted the new contrivance lately exhibited by Sir Francis Delaval on Weſtminſter bridge: whenever they begin to ſnort and toſs up their heads, he touches the ſpring, throws them looſe, and away they go, leaving his lordſhip ſafe and ſnug, and as much at his eaſe as if he ſat on a woolpack.”

The letter, of which this is an extract, was printed in the Public Advertiſer; and is ſaid to have contributed, in no ſmall degree, to leſſen the popularity of the illuſtrious ſtateſman againſt whom it was written. The miniſtry, indeed, which he had formed, conſiſted of very heterogeneous materials, and was not heartily approved of by the nation. It therefore ſoon fell in pieces by its own diſcord, and Lord Chatham retired in diſguſt.

The parliament being diſſolved in 1768, Burke was re-elected for Wendover, and took his ſeat, when the houſe met, in November. The duke of Grafton was now prime miniſter, and was oppoſed by two powerful parties in parliament; that of the marquis of Rockingham, and that of which Mr Grenville was conſidered as the leader. Theſe two parties, however, differed widely between themſelves. Mr Grenville had publiſhed a pamphlet, intitled, *The Preſent State of the Nation;* in which he very ably vindicated his own meaſures, and of courſe condemned the meaſures of thoſe who had ſucceeded him; and Burke replied to him, with greater eloquence, but, perhaps, with leſs of argument, in a tract, intitled *Obſervations on the Preſent State of the Nation,* in which he makes a very high panegyric on his own patron, and the connections of the party, and animadverts with cutting ſeverity on their ſucceſſors in office.

About this period commenced the national frenzy which was excited by the expulſion of Wilkes from the houſe of commons, *for having printed and publiſhed a ſeditious libel, and three obſcene and impious libels.* In the controverſy to which this tranſaction gave riſe, Burke and Johnſon took oppoſite ſides. Johnſon, in his *Falſe Alarm,* contends, with great ability, that the expulſion of a member from the houſe of commons for the commiſſion of a crime, amounts to a diſqualification of that member from ſitting in the parliament from which he is expelled; whilſt Burke, though he diſapproved of the conduct of Wilkes as much as his friend, laboured to prove, that nothing but an act of the legiſlature can diſqualify any perſon from ſitting in parliament who is regularly choſen, by a majority of electors, to fill a vacant ſeat. It does not appear that this difference of opinion produced the ſmalleſt abatement of mutual regard between him and Johnſon. They both attended the weekly club, and were as much pleaſed with each other as formerly.

The proceedings of the Grafton adminiſtration, reſpecting Wilkes and other ſubjects, gave riſe to the celebrated *Letters of Junius.* That thoſe compoſitions were, in clearneſs, neatneſs, and preciſion of ſtyle, infinitely ſuperior to perhaps every other ſeries of newſpaper invectives, has never been controverted; and that they diſplay a vaſt extent of hiſtorical and political information, is known to all who are not themſelves ſtrangers to the hiſtory of Great Britain. Unclaimed by any author, and ſuperior to the productions of moſt authors, they have been given to Burke, to his brother Richard, a man likewiſe of very bright talents, to Mr Hamilton, and to Lord George Germaine. We ſhould hardly heſitate to adopt the opinion of thoſe who aſcribe them to Burke, had he not diſavowed them to his friend Johnſon. “ I ſhould have believed Burke to be Junius (ſaid Johnſon), becauſe I know no man but Burke who is capable of writing theſe letters; but Burke *ſpontaneouſly* denied it to me. The caſe would have been different had I *aſked* him if he was the author. A man may think he has a right to deny when ſo queſtioned as to an anonymous publication.” The difference between the ſtyle of theſe letters and that of Burke's acknowledged writings, would have had no weight with us; becauſe ſuch was his command of language, that he could aſſume, and occaſionally did aſſume, any ſtyle which he choſe to imitate. He had already ſo cloſely imitated the very different ſtyles of Lucas and Bolingbroke as to deceive the public; and what was to hinder him from imitating the ſtyle of Lord George Germaine, which certainly has a ſtrong reſemblance to that of Junius? We think, however, with Johnſon, that his *ſpontaneous diſavowal* of theſe letters ought to be held as ſufficient proof that he was not their author.

Burke had now gotten a very pleaſant villa near Beaconsfield in Buckinghamſhire; and being one of the freeholders of the county, he drew up a petition to the king, complaining of the conduct of the houſe of commons reſpecting the Middleſex election, and praying for a diſſolution of the parliament. The petition, though explicit and firm, was temperate and decorous, and as unlike to one on the ſame ſubject from the livery of London, as the principles of a moderate Whig are to thoſe of a turbulent democrate.

About this period he ſtated very clearly his own political principles in a pamphlet intitled, “ Thoughts on the Cauſes of the Preſent Diſcontents;” and his plan for removing theſe diſcontents had not a grain of democracy in its compoſition. He propoſed to place the government in the hands of an open ariſtocracy of talents, virtue, property, and rank, combined together on avowed principles, and ſupported by the approbation and confidence of the people; and the ariſtocracy which he thought fitteſt for this great truſt, was a combination of thoſe Whig families which had moſt powerfully ſupported the revolution and conſequent eſtabliſhments. He expreſſed, in ſtrong terms, his diſapprobation of any change in the conſtitution and duration of parliament; and declared himſelf as averſe from an adminiſtration which ſhould have no other ſupport than popular favour, as from one brought forward merely by the influence of the court.

In this plan there is not that wiſdom or liberality which might have been expected from a man of Burke's cultivated mind and extenſive reading. The Whigs, when in power, had been as venal as the Tories; and the impriſonment of Lord Oxford, the baniſhment of Atterbury biſhop of Rocheſter, and the reſolution of the 18th of November, Mr Fox introduced his famous India-bill, into the merits of which it is foreign from our purpoſe to enter: ſuffice it to ſay, that after being ſtrongly ſupported by Burke, and ably oppoſed by Pitt and Dundas, it paſſed the houſe of commons by a very great majority; but was loſt in the houſe of peers, and viewed by the king in ſuch a light, that he determined on an entire change of adminiſtration.

Mr Pitt was now placed at the head of the treaſury, where he has remained ever ſince, notwithſtanding the violent and powerful oppoſition which he met with at firſt from North and Fox and their coaleſced friends: the voice of the nation has been on his ſide; and that voice will always drown the bellowings of patriotiſm.

The principal events in which Burke ſignalized himſelf, ſince the year 1784, were the trial of Haſtings, the deliberations of the houſe on the propoſed regency during the lamented illneſs of the king, and the French revolution; and on each of theſe occaſions he diſplayed talents which aſtoniſhed the nation. He has, indeed, been ſeverely blamed for the pertinacity with which he proſecuted Mr Haſtings, and his conduct has been attributed to very unworthy motives; but of this there is neither proof nor probability. The temperament of his mind was ſuch, that, into whatever meaſure he entered, he entered with a degree of ardour of which cooler heads can hardly form a conception. Burke was but one member of a committee which found, or thought it found, evidences of the guilt of Haſtings; and, in forming his opinion, it is little likely that he ſhould have been biaſſed by intereſt or reſentment, whoſe delicate ſenſe of rectitude would not permit him to retain a penſion when he could no longer ſupport the party of that friend who had obtained it for him.

When the eſtabliſhment of a regency was thought neceſſary, he took the part, as it was called, of the prince of Wales, in oppoſition to the plan propoſed by Lord Thurlow and the miniſter; and we doubt not but he was actuated by the pureſt principles: but the language which he uſed in the houſe was vehement, and ſome of his expreſſions were highly indecent. Our regard for his memory makes us wiſh to forget them.

Soon after the recovery of the king, the attention of Burke was attracted to the moſt momentous event of modern times;—an event which has convulſed all Europe, and of which, from the very firſt, his ſagacity foreſaw the conſequences. Many of his friends in parliament, as well as numbers of wiſe and good men out of it, augured, from the meeting of the ſtates general of France, great benefit to that nation, of which the government was conſidered as deſpotic and oppreſſive; and ſome were ſanguine enough to prognoſticate a new and happy order of things to all the nations connected with France, when its government ſhould become more free. Burke thought very differently: He was well acquainted with the genius of the French people, and with the principles of thoſe philoſophers, as they called themſelves, by whom a total revolution in church and ſtate had long been projected; and from the commencement of their career in the conſtituent aſſembly, when they eſtabliſhed, as the foundation of all legal government, the metaphyſical doctrine of *the rights of man*, he predicted that torrent of anarchy and irreligion which they have ſince attempted to pour over all Europe. Fox and ſome of the other leading men in oppoſition affected to conſider this as a vain fear; and a coolneſs took place between them and Burke, though they ſtill acted together in parliament. At laſt, perceiving the French doctrines of liberty and equality and atheiſm, ſpreading through this nation, not only among thoſe who had talents for ſuch diſquiſitions, but in clubs and ſocieties, of which the members could be no judges of metaphyſical reaſonings, he expreſſed his apprehenſion of the conſequences in the houſe of commons. This brought on a violent altercation between him and Fox, who was ſupported by Sheridan; and a rupture took place between theſe old friends which was never healed. He no more attended the meetings of the oppoſition members; and in 1790 he publiſhed his celebrated *Reflections on the French Revolution.*

By the friends of government this work was admired as the moſt ſeaſonable, as well as one of the ableſt, defences of the Britiſh conſtitution that ever was written; whilſt Fox and his friends, with the great body of Engliſh diſſenters, though they admitted it to be the offſpring of uncommon genius, affected to conſider it as declamatory rather than argumentative, and as inconſiſtent with the principles which its author had hitherto uniformly maintained. Many anſwers were written to it; of which the moſt conſpicuous were *Vindiciæ Gallicæ* by Mr Mac Intoſh, and *The Rights of Man* by Thomas Paine. To theſe Burke deigned not to make a direct reply. He vindicated his general principles, as well as ſome of his particular reaſonings, in *A Letter to a Member of the National Aſſembly;* and he very completely evinced the conſiſtency of his principles in his *Appeal from the New to the Old Whigs.*

Of this great work, for great it undoubtedly is, the merits as well as the demerits have been much exaggerated; and ſome have made it a queſtion, Whether it has on the whole been productive of good or of harm? By the enemies of the author, it is repreſented as having given riſe to the ſpirit of diſcontent, by exciting ſuch writers as Paine and his adherents, who, but for the provocation given by *The Reflections*, might have remained in ſilence and obſcurity. This was from the firſt a very improbable ſuppoſition; for the ſpirit of democracy has at all times been reſtleſs: but ſince the appearance of Profeſſor Robiſon's *Proofs of a conſpiracy*, and Barruel's *Hiſtory of Jacobiniſm*, it muſt be known to every reader to be a ſuppoſition contrary to fact. The conſpirators were buſy long before Burke wrote his *Reflections;* and the friends of order and religion are his debtors, for having ſo forcibly rouſed them from their ſlumber, and put them on their guard. With reſpect to compoſition, it is certainly neither ſo energetic nor ſo argumentative as the political tracts of Johnſon, to which ſome have affected to conſider it as ſuperior; but it is more poetical, gives ſcope for a greater diſplay of the knowledge of human nature; and being written on a more intereſting ſubject, it has had a much greater number of readers than thoſe unrivalled pieces of political controverſy.

Burke being now aſſociated with Mr Pitt, continued to write from time to time memorials and remarks on the ſtate of France, and the alliance that was formed againſt the new order of things in that diſtracted country, of which ſome have been publiſhed ſince his death; and having reſolved to quit the buſtle of public life as ſoon as the trial of Mr Haſtings ſhould be concluded, he

Burke.

Burke || Burlington.

he vacated his ſeat when that gentleman was acquitted, and retired to his villa at Beaconsfield, where on the 2d of Auguſt 1794 he met with a heavy domeſtic loſs in the death of his only ſon. In the beginning of the ſame year he had loſt his brother Richard, whom he tenderly loved: but though this reiterated ſtroke of death deeply affected him, it never relaxed the vigour of his mind, nor leſſened the intereſt which he took in the public weal.

In this retreat, while he was labouring for the good of all around him, he was diſturbed by a very unprovoked attack upon his character by ſome diſtinguiſhed ſpeakers in the houſe of peers. Soon after the death of his ſon the king was graciouſly pleaſed to beſtow a penſion on him and Mrs Burke; and this thoſe noble lords were pleaſed to repreſent as the reward of what they termed the change of his principles and the deſertion of his friends. The injuſtice of this charge muſt be obvious to every impartial mind, ſince the penſion was given after he had retired from parliament, and could not by his eloquence either ſupport the miniſtry or gall the oppoſition. He was not a man to ſubmit tamely to ſuch an inſult. He publiſhed a letter on the occaſion, addreſſed to a noble lord (Earl Fitzwilliam), in which he repels the attack on his character, and retaliates on thoſe by whom it was made, in terms of ſuch eloquent and keen ſarcaſm, as will be read with admiration as long as the language of the letter ſhall be underſtood.

Burke having employed every effort which benevolence and wiſdom could deviſe to ſtimulate civilized governments to unite in oppoſition to the impiety and anarchy of France, laboured likewiſe in private to relieve thoſe who had ſuffered exile and proſcription from the direful ſyſtem. Through his influence a ſchool was eſtabliſhed in his neighbourhood for the education of thoſe whoſe parents, for their adherence to principle, were rendered unable to afford to their children uſeful inſtruction; and that ſchool, which on his deathbed he recommended to Mr Pitt, continues to flouriſh under his powerful protection.

When the appearance of melioration in the principles and government of France induced our ſovereign to make overtures of peace to the French directory, Burke reſumed his pen; and in a ſeries of letters, intitled, *Thoughts on the Proſpect of a Regicide Peace,* diſplayed a force of genius which is certainly not ſurpaſſed, and perhaps not equalled, even in his far famed *Reflections on the French Revolution.* This was his laſt work, and was conſidered by himſelf as in its nature teſtamentary.

From the beginning of June 1797 his health rapidly declined; but his underſtanding exerted itſelf with undiminiſhed force and uncontracted range; and his diſpoſitions retained all their amiable ſweetneſs. On the 7th of July, when the French revolution was mentioned, he ſpoke with pleaſure of the conſcious rectitude of his own intentions in what he had done and written reſpecting it; intreated thoſe about him to believe, that if any unguarded expreſſion of his on the ſubject had offended any of his former friends, no offence was by him intended; and he declared his unfeigned forgiveneſs of all who had on account of his writings, or for any other cauſe, endeavoured to do him an injury. On the day following he deſired to be carried to another room; and whilſt one of his friends, aſſiſted by ſome ſervants, was complying with his requeſt, Mr Burke faintly uttering, "God bleſs you," fell back and expired in the 68th year of his age.

From this detail, we truſt that our readers are already ſufficiently acquainted with his general character. In genius, variety of knowledge, and readineſs of expreſſion, Johnſon alone of all his contemporaries could be conſidered as his rival; and, like that great man, he took every opportunity, eſpecially during his laſt illneſs, to declare his unſhaken belief of the Chriſtian religion, his veneration for ſincere Chriſtians of all perſuaſions, and his own preference of the church of England. On the worſhip of that church he had indeed through the whole of his life been a regular and devout attendant; and the tears which the poor, in the neighbourhood of his villa, ſhed at his funeral, gave ſufficient evidence that his faith had been productive of charity. In his public conduct, the irritability of his temper, and the ardour of his imagination, ſometimes hurried him into the exceſſes of a mere party-man; but we believe that his great religious and political principles never varied. He has himſelf characteriſed his public conduct in the concluſion of his Reflections on the French Revolution, when he ſays, that "they come from one who has been no tool of power, no flatterer of greatneſs, and who in his laſt acts does not wiſh to belie the tenor of his life; from one who wiſhes to preſerve conſiſtency, but who would preſerve conſiſtency by varying his means to ſecure the unity of his end; and when the equipoiſe of the veſſel in which he ſails may be endangered by overloading it upon one ſide, is deſirous of carrying the ſmall weight of his reaſons to that which may preſerve the equipoiſe."

BURKE *Co.* in Morgan diſtrict, N. Carolina, has 8118 inhabitants, including 595 ſlaves. Its capital is Morgantown.—*Morse.*

Burke *Co.* in the Lower diſtrict of Georgia, contains 9467 inhabitants, including 595 ſlaves. Its chief towns are Louiſville, and Wayneſborough.—*ib.*

Burke, a townſhip in Caledonia co. in Vermont; diſtant from Bennington, 134 miles N. E.—*ib.*

BURLINGTON, is a pleaſant townſhip, the chief in Chittendon co. Vermont, ſituated on the S. ſide of Onion River, on the E. bank of Lake Champlain. It has 332 inhabitants. It is in this healthy and agreeable ſituation, that the governor and patrons of the college of Vermont, intend to found a ſeminary of learning, where youth of all denominations may receive an education.

In digging a well about 15 rods from the bank of the river, frogs have been found, at the depth of 25 feet, where no cavities or communication with the water appeared, through which they might have paſſed; and when expoſed to the heat of the ſun they became full of life and activity. Here ſtumps of trees are found 40 feet deep. It is conjectured that theſe animals muſt have been covered up ſome hundred years ago, by ſome inundation of the river. Burlington is 22 miles northerly of Vergennes, 122 from Bennington, and 332 in the ſame direction from New-York city, N. lat. 44. 30.—*ib.*

Burlington, or *Ouineaſkea Bay,* on the E. ſide of Lake Champlain, about 34 miles N. by E. from Crown too, the Grave of Blair, the far-famed Elegy of Gray, the Paradiſe Loſt of Milton, perhaps the Minſtrel of Beattie, were ſo commonly read, even among thoſe with whom Burns would naturally aſſociate, that poetical curioſity, although even leſs ardent than his, could in ſuch circumſtances have little difficulty in procuring them.

With ſuch means to give his imagination a poetical bias, and to favour the culture of his taſte and genius, Burns gradually became a poet. He was not, however, one of thoſe forward children who, from a miſtaken impulſe, begin prematurely to write and to rhyme, and hence never attain to excellence. Converſing familiarly for a long while with the works of thoſe poets who were known to him; contemplating the aſpect of nature in a diſtrict which exhibits an uncommon aſſemblage of the beautiful and the ruggedly grand, of the cultivated and the wild; looking upon human life with an eye quick and keen, to remark as well the ſtronger and leading, as the nicer and ſubordinate, features of character; to diſcriminate the generous, the honourable, the manly, in conduct, from the ridiculous, the baſe, and the mean—he was diſtinguiſhed among his fellows for extraordinary intelligence, good ſenſe, and penetration, long before others, or perhaps even himſelf, ſuſpected him to be capable of writing verſes. His mind was mature, and well ſtored with ſuch knowledge as lay within his ſearch: he had made himſelf maſter of powers of language, ſuperior to thoſe of almoſt any former writer in the Scottiſh dialect, before he conceived the idea of ſurpaſſing Ramſay and Ferguſon.

Hitherto he had converſed intimately only with peaſants on his own level; but having got admiſſion into the fraternity of free-maſons, he had the fortune, whether good or bad, to attract in the lodges the notice of gentlemen better qualified than his more youthful companions to call forth the powers of his mind, and to ſhow him that he was indeed a poet. A maſonic ſong, a ſatirical epigram, a rhyming epiſtle to a friend, attempted with ſucceſs, taught him to know his own powers, and gave him confidence to try taſks more arduous, and which ſhould command ſtill higher burſts of applauſe.

The annual celebration of the ſacrament of the Lord's Supper, in the rural pariſhes of Scotland, has much in it of thoſe old popiſh feſtivals, in which ſuperſtition, traffic, and amuſement, uſed to be ſtrangely intermingled. Burns ſaw, and ſeized in it one of the happieſt of all ſubjects, to afford ſcope for the diſplay of that ſtrong and piercing ſagacity by which he could almoſt intuitively diſtinguiſh the reaſonable from the abſurd, and the becoming from the ridiculous; of that pictureſque power of fancy, which enabled him to repreſent ſcenes, and perſons, and groupes, and looks, attitude, and geſtures, in a manner almoſt as lively and impreſſive, even in words, as if all the artifices and energies of the pencil had been employed; of that knowledge which he had neceſſarily acquired of the manners, paſſions, and prejudices of the ruſtics around him, of whatever was ridiculous, no leſs than of whatever was affectingly beautiful in rural life.

A thouſand prejudices of Popiſh, and perhaps too of ruder Pagan ſuperſtition, have from time immemorial been connected in the minds of the Scottiſh peaſantry, with the annual recurrence of the Eve of the Feſtival of all the Saints or Halloween. Theſe were all intimately known to Burns, and had made a powerful impreſſion upon his imagination and feelings. He choſe them for the ſubject of a poem, and produced a piece which is almoſt to frenzy the delight of thoſe who are beſt acquainted with its ſubject; and which will not fail to preſerve the memory of the prejudices and uſages which it deſcribes, when they ſhall perhaps have ceaſed to give one merry evening in the year to the cottage fireſide.

The ſimple joys, the honeſt love, the ſincere friendſhip, the ardent devotion of the cottage; whatever in the more ſolemn part of the ruſtic's life is humble and artleſs, without being mean or unſeemly—or tender and dignified, without aſpiring to ſtilted grandeur—or to unnatural, buſkined pathos, had deeply impreſſed the imagination of the riſing poet; had, in ſome ſort, wrought itſelf into the very texture of the fibres of his ſoul. He tried to expreſs in verſe what he moſt tenderly felt, what he moſt enthuſiaſtically imagined; and produced the *Cottar's Saturday's Night.*

Theſe pieces, the true effuſions of genius, informed by reading and obſervation, and prompted by its own native ardour, as well as by friendly applauſe, were ſoon handed about among the moſt diſcerning of Burns's acquaintance; and were by every new reader peruſed and reperuſed, with an eagerneſs of delight and approbation which would not ſuffer their author long to withhold them from the preſs. A ſubſcription was propoſed, was earneſtly promoted by ſome gentlemen, who were glad to intereſt themſelves in behalf of ſuch ſignal poetical merit; was ſoon crowded with the names of a conſiderable number of the inhabitants of Ayrſhire, who in the proffered purchaſe ſought not leſs to gratify their own paſſion for Scottiſh poeſy, than to encourage the wonderful ploughman. At Kilmarnock were the poems of Burns for the firſt time printed. The whole edition was quickly diſtributed over the country.

It is hardly poſſible to expreſs with what eager admiration and delight they were every where received.—They eminently poſſeſſed all thoſe qualities which the moſt invariably contribute to render any literary work quickly and permanently popular. They were written in a phraſeology, of which all the powers were univerſally felt; and which being at once antique, familiar, and now rarely written, was hence fitted to ſerve all the dignified and pictureſque uſes of poetry, without making it unintelligible. The imagery, the ſentiments, were at once faithfully natural, and irreſiſtibly impreſſive and intereſting. Thoſe topics of ſatire and ſcandal in which the ruſtic delights; that humorous imitation of character, and that witty aſſociation of ideas familiar and ſtriking, yet not naturally allied to one another, which has force to ſhake his ſides with laughter; thoſe fancies of ſuperſtition, at which he ſtill wonders and trembles; thoſe affecting ſentiments and images of true religion, which are at once dear and awful to his heart, were all repreſented by Burns with all a poet's magic power. Old and young, high and low, grave and gay, learned or ignorant, all were alike delighted, agitated, tranſported.

In the mean time, ſome few copies of theſe faſcinating poems found their way to Edinburgh; and having been read to Dr Blacklock, they obtained his warmeſt approbation. In the beginning of the winter 1786-7

Burns went to Edinburgh, where he was received by Dr Blacklock with the moſt flattering kindneſs, and introduced to every man of generoſity and taſte among that good man's friends. Multitudes now vied with each other in patronizing the ruſtic poet. Thoſe who poſſeſſed at once true taſte and ardent philanthrophy were ſoon earneſtly united in his praiſe; they who were diſpoſed to favour any good thing belonging to Scotland, purely becauſe it was Scottiſh, gladly joined the cry; thoſe who had hearts and underſtanding to be charmed, without knowing why, when they ſaw their native cuſtoms, manners, and language, made the ſubjects and the materials of poeſy, could not ſuppreſs that voice of feeling which ſtruggled to declare itſelf for Burns: for the diſſipated, the licentious, the malignant wits, and the freethinkers, he was ſo unfortunate as to have ſatire, and obſcenity, and ridicule of things ſacred, ſufficient to captivate their fancies; even for the pious he had paſſages in which the inſpired language of devotion might ſeem to come mended from his pen.

Thus did Burns, ere he had been many weeks in Edinburgh, find himſelf the object of univerſal curioſity, favour, admiration, and fondneſs. He was ſought after, courted with attentions the moſt reſpectful and aſſiduous, feaſted, flattered, careſſed, treated by all ranks as the firſt boaſt of his country, whom it was ſcarcely poſſible to honour and reward to a degree equal to his merits. In compariſon with the general favour which now promiſed to more than crown his moſt ſanguine hopes, it could hardly be called praiſe at all which he had obtained in Ayrſhire.

In this poſture of our poet's affairs a new edition of his poems was earneſtly called for. He ſold the copy-right for one hundred pounds; but his friends at the ſame time ſuggeſted, and actively promoted a ſubſcription for an edition, to be publiſhed for the benefit of the author, ere the bookſeller's right ſhould commence. Thoſe gentlemen who had formerly entertained the public of Edinburgh with the periodical publication of the papers of the *Mirror*, having again combined their talents in producing the *Lounger*, were at this time about to conclude this laſt ſeries of papers: yet before the Lounger relinquiſhed his pen, he dedicated a number to a commendatory criticiſm of the poems of the Ayrſhire bard.

The ſubſcription-papers were rapidly filled; and it was ſuppoſed that the poet might derive from the ſubſcription and the ſale of his copy-right a clear profit of at leaſt 700 pounds.

The converſation of even the moſt eminent authors is often found to be ſo unequal to the fame of their writings, that he who reads with admiration can liſten with none but ſentiments of the moſt profound contempt. But the converſation of Burns was in compariſon with the formal and exterior circumſtances of his education, perhaps even more wonderful than his poetry. He affected no ſoft air or graceful motions of politeneſs, which might have ill accorded with the ruſtic plainneſs of his native manners. Conſcious ſuperiority of mind taught him to aſſociate with the great, the learned, and the gay, without being overawed into any ſuch baſhfulneſs as might have made him confuſed in thought, or heſitating in elocution. He poſſeſſed withal an extraordinary ſhare of plain common ſenſe or mother-wit, which prevented him from obtruding upon perſons, of whatever rank with whom he was admitted to converſe, any of thoſe effuſions of vanity, envy, or ſelf-conceit, in which authors are exceedingly apt to indulge, who have lived remote from the general practice of life, and whoſe minds have been almoſt excluſively confined to contemplate their own ſtudies and their own works. In converſation he diſplayed a ſort of intuitive quickneſs and rectitude of judgment upon every ſubject that aroſe. The ſenſibility of his heart, and the vivacity of his fancy, gave a rich colouring to whatever reaſoning he was diſpoſed to advance; and his language in converſation was not at all leſs happy than in his writings. For theſe reaſons, thoſe who had met and converſed with him once, were pleaſed to meet and to converſe with him again and again.

For ſome time he converſed only with the virtuous, the learned, and the wiſe; and the purity of his morals remained uncontaminated. But, alas! he fell, as others have fallen in ſimilar circumſtances. He ſuffered himſelf to be ſurrounded by a race of miſerable beings, who were proud to tell that they had been in company with Burns, and had ſeen Burns as looſe and as fooliſh as themſelves. He was not yet irrecoverably loſt to temperance and moderation; but he was already almoſt too much captivated with their wanton rivals, to be ever more won back to a faithful attachment to their more ſober charms. He now alſo began to contract ſomething of new arrogance in converſation. Accuſtomed to be among his favourite aſſociates what is vulgarly but expreſſively called *the cock of the company*, he could ſcarcely refrain from indulging in ſimilar freedom and dictatorial deciſion of talk, even in the preſence of perſons who could leſs patiently endure his preſumption.

The ſubſcription edition of his poems, in the mean time, appeared; and although not enlarged beyond that which came from the Kilmarnock preſs by any new pieces of eminent merit, did not fail to give entire ſatisfaction to the ſubſcribers. He was now to cloſe accounts with his bookſeller and his printer, to retire to the country with his profits in his pocket, and to fix upon a plan for his future life. He talked loudly of independence of ſpirit and ſimplicity of manners, and boaſted his reſolution to return to the plough; yet ſtill he lingered in Edinburgh, week after week, and month after month, perhaps expecting that one or other of his noble patrons might procure him ſome permanent and competent annual income, which ſhould ſet him above all neceſſity of future exertions to earn for himſelf the means of ſubſiſtence; perhaps unconſciouſly reluctant to quit the pleaſures of that voluptuous town-life to which he had for ſome time too willingly accuſtomed himſelf. An accidental diſlocation or fracture of an arm or a leg confining him for ſome weeks to his apartment, left him during this time leiſure for ſerious reflection; and he determined to retire from the town without longer delay. None of all his patrons interpoſed to divert him from his purpoſe of returning to the plough, by the offer of any ſmall penſion, or any ſinecure place of moderate emolument, ſuch as might have given him competence without withdrawing him from his poetical ſtudies. It ſeemed to be forgotten that a ploughman thus exalted into a man of letters was unfitted for his former toils, without being regularly qualified to enter the career of any new profeſſion; and that it became incumbent upon thoſe patrons who had called him from the plough, not merely to make him their companion in the hour of riot, not ſimply to fill his purſe with gold for a few tranſient expences, but to ſecure him as far as was poſſible from being ever overwhelmed in diſtreſs in conſequence of the favour which they had ſhown him, and of the habits of life into which they had ſeduced him. Perhaps indeed the ſame deluſion of fancy betrayed both Burns and his patrons into the miſtaken idea, that, after all which had paſſed, it was ſtill poſſible for him to return in cheerful content to the homely joys and ſimple toils of undiſſipated rural life.

In this temper of Burns's mind, in this ſtate of his fortune, a farm and the exciſe were the objects upon which his choice ultimately fixed for future employment and ſupport. By the ſurgeon who attended him during his illneſs, he was recommended with effect to the commiſſioners of exciſe; and Patrick Millar, Eſq; of Dalſwinton, deceived, like Burns himſelf and Burns's other friends, into an idea that the poet and exciſeman might yet be reſpectable and happy as a farmer, generouſly propoſed to eſtabliſh him in a farm, upon conditions of leaſe which prudence and induſtry might eaſily render exceedingly advantageous. Burns eagerly accepted the offers of this benevolent patron. Two of the poet's friends from Ayrſhire were invited to ſurvey that farm in Dumfriesſhire which Mr Millar offered. A leaſe was granted to the poetical farmer at that annual rent which his own friends declared that the due cultivation of his farm might eaſily enable him to pay. What yet remained of the profits of his publication was laid out in the purchaſe of farm-ſtock; and Mr Millar might, for ſome ſhort time, pleaſe himſelf with the perſuaſion that he had approved himſelf the liberal patron of genius; had acquired a good tenant upon his eſtate; and had placed a deſerving man in the very ſituation in which alone he himſelf deſired to be placed, in order to be happy to his wiſhes.

Burns, with his Jane, whom he now married, took up their reſidence upon his farm. The neighbouring farmers and gentlemen, pleaſed to obtain for an inmate among them the poet by whoſe works they had been delighted, kindly ſought his company, and invited him to their houſes. He found an inexpreſſible charm in ſitting down beſide his wife, at his own fireſide; in wandering over his own grounds; in once more putting his hand to the ſpade and the plough; in forming his incloſures, and managing his cattle. For ſome months he felt almoſt all that felicity which fancy had taught him to expect in his new ſituation. He had been for a time idle; but his muſcles were not yet unbraced for rural toil. He now ſeemed to find a joy in being the huſband of the miſtreſs of his affections, in ſeeing himſelf the father of her children, ſuch as might promiſe to attach him for ever to that modeſt, humble, and domeſtic life, in which alone he could hope to be permanently happy. Even his engagements in the ſervice of the exciſe did not, at the very firſt, threaten neceſſarily to debaſe him by aſſociation with the mean, the groſs, and the profligate, to contaminate the poet, or to ruin the farmer.

But it could not be: it was not poſſible for Burns now to aſſume that ſoberneſs of fancy and paſſions, that ſedateneſs of feeling, thoſe habits of earneſt attention to groſs and vulgar cares, without which ſucceſs in his new ſituation was not to be expected. A thouſand difficulties were to be encountered and overcome, much money was to be expended, much weary toil was to be exerciſed, before his farm could be brought into a ſtate of cultivation, in which its produce might enrich the occupier. This was not a proſpect encouraging to a man who had never loved labour, and who was at this time certainly not at all diſpoſed to enter into agriculture with the enthuſiaſm of a projector. The buſineſs of the exciſe too, as he began to be more and more employed in it, diſtracted his mind from the care of his farm, led him into groſs and vulgar ſociety, and expoſed him to many unavoidable temptations to drunken exceſs, ſuch as he had no longer ſufficient fortitude to reſiſt. Amidſt the anxieties, diſtractions, and ſeducements which thus aroſe to him, home became inſenſibly leſs and leſs pleaſing; even the endearments of his Jane's affection began to loſe their hold on his heart; he became every day leſs and leſs unwilling to forget in riot thoſe gathering ſorrows which he knew not to ſubdue.

Mr Millar and ſome others of his friends would gladly have exerted an influence over his mind which might have preſerved him in this ſituation of his affairs, equally from deſpondency and from diſſipation; but Burns's temper ſpurned all controul from his ſuperiors in fortune. He reſented, as an arrogant encroachment upon his independence, that tenor of conduct by which Mr Millar wiſhed to turn him from diſſolute conviviality, to that ſteady attention to the buſineſs of his farm, without which it was impoſſible to thrive in it. His croſſes and diſappointments drove him every day more and more into diſſipation; and his diſſipation tended to enhance whatever was diſagreeable and perplexing in the ſtate of his affairs. He ſunk, by degrees, into the boon companion of mere exciſemen; and almoſt every drunken fellow, who was willing to ſpend his money laviſhly in the alehouſe, could eaſily command the company of Burns. The care of his farm was thus neglected; waſte and loſſes wholly conſumed his little capital; he reſigned his leaſe into the hands of his landlord; and retired, with his family, to the town of Dumfries, determining to depend entirely for the means of future ſupport upon his income as an exciſe-officer.

Yet during this unfortunate period of his life, which paſſed between his departure from Edinburgh to ſettle in Dumfriesſhire, and his leaving the country in order to take up his reſidence in the town of Dumfries, the energy and activity of his intellectual powers appeared to have been not at all impaired. In a collection of Scottiſh ſongs, which were publiſhed (the words with the muſic) by Mr Johnſon, engraver in Edinburgh, in 4 vols 8vo, Burns, in many inſtances, accommodated new verſes to the old tunes with admirable felicity and ſkill. He aſſiſted in the temporary inſtitution of a ſmall ſubſcription library, for the uſe of a number of the well-diſpoſed peaſants in his neighbourhood. He readily aided, and by his knowledge of genuine Scottiſh phraſeology and manners greatly enlightened, the antiquarian reſearches of the late ingenious Captain Groſe. He ſtill carried on an epiſtolary correſpondence, ſometimes gay, ſportive, humorous, but always enlivened by bright flaſhes of genius, with a number of his old friends, and on a very wide diverſity of topics. At times, as it ſhould ſeem from his writings of this period, he reflected, with inexpreſſible heart-bitterneſs, on the high hopes from which he had fallen; on the errors of moral conduct into which he had been hurried by the ardour of his ſoul; and in ſome meaſure by the very generoſity of his nature; on the diſgrace and wretchedneſs into which he ſaw himſelf rapidly ſinking; on the ſorrow with which his miſconduct oppreſſed the heart of his Jane; on the want and deſtitute miſery in which it ſeemed probable that he muſt leave her and their infants; nor amidſt theſe agonizing reflections did he fail to look, with an indignation half invidious, half contemptuous, on thoſe who, with moral habits not more excellent than his, with powers of intellect far inferior, yet baſked in the ſun-ſhine of fortune, and were loaded with the wealth and honours of the world, while his follies could not obtain pardon, nor his wants an honourable ſupply. His wit became from this time more gloomily ſarcaſtic; and his converſation and writings began to aſſume ſomething of a tone of miſanthropical malignity, by which they had not been before, in any eminent degree, diſtinguiſhed. But with all theſe failings, he was ſtill that exalted mind which had raiſed itſelf above the depreſſion of its original condition: with all the energy of the lion, pawing to ſet free his hinder limbs from the yet encumbering earth, he ſtill appeared *not leſs than archangel ruined!*

His morals were not mended by his removal from the country. In Dumfries his diſſipation became ſtill more deeply habitual; he was here more expoſed than in the country to be ſolicited to ſhare the riot of the diſſolute and the idle: fooliſh young men flocked eagerly about him, and from time to time preſſed him to drink with them, that they might enjoy his wicked wit. The Caledonian Club, too, and the Dumfriesſhire and Galloway Hunt, had occaſional meetings in Dumfries after Burns went to reſide there, and the poet was of courſe invited to ſhare their conviviality, and heſitated not to accept the invitation.

In the intervals between his different fits of intemperance, he ſuffered ſtill the keeneſt anguiſh of remorſe, and horribly afflictive foreſight. His Jane ſtill behaved with a degree of maternal and conjugal tenderneſs and prudence, which made him feel more bitterly the evil of his miſconduct, although they could not reclaim him. At laſt crippled, emaciated, having the very power of animation waſted by diſeaſe, quite broken-hearted by the ſenſe of his errors, and of the hopeleſs miſeries in which he ſaw himſelf and his family depreſſed; with his ſoul ſtill tremblingly alive to the ſenſe of ſhame, and to the love of virtue; yet even in the laſt feebleneſs, and amid the laſt agonies of expiring life, yielding readily to any temptation that offered the ſemblance of intemperate enjoyment, he died at Dumfries, in the ſummer of 1796, while he was yet three or four years under the age of forty, furniſhing a melancholy proof of the danger of *ſuddenly* elevating even the greateſt mind above its original level.

After his death it quickly appeared that his failings had not effaced from the minds of his more reſpectable acquaintance either the regard which had once been won by his ſocial qualities, or the reverence due to his intellectual talents. The circumſtances of want in which he left his family were noticed by the gentlemen of Dumfries with earneſt commiſeration. His funeral was celebrated by the care of his friends with a decent ſolemnity, and with a numerous attendance of mourners, ſufficiently honourable to his memory. Several copies of verſes were inſerted in different newſpapers upon the occaſion of his death. A contribution, by ſubſcription, was propoſed, for the purpoſe of raiſing a ſmall fund, for the decent ſupport of his widow, and the education of his infant children.

From the preceding detail of the particulars of this poet's life, the reader will naturally and juſtly infer him to have been an honeſt, proud, warm-hearted man; of high paſſions and ſound underſtanding, and a vigorous and excurſive imagination. He was never known to deſcend to any act of deliberate meanneſs. In Dumfries he retained many reſpectable friends even to the laſt; and it may be doubted whether any poet of the preſent age has exerciſed a greater power over the minds of his readers. Burns has not failed to command one remarkable ſort of homage, ſuch as is never paid but to great original genius; a crowd of poetaſters ſtarted up to imitate him, by writing verſes as he had done in the Scottiſh dialect; but, *O imitatores! ſervum pecus!* To write rugged rhymes, in antiquated phraſe, is not to imitate the poetry of Burns.

BURRAMPOOTER. See Sandpu, *Encycl.*

BUSHWICK, a ſmall, but pleaſant town, in King's co. Long Iſland, New-York. The inhabitants, 540 in number, are chiefly of Dutch extraction; 99 of theſe are electors.—*Morse.*

BUTTER is a ſubſtance ſo well known, that it is needleſs to give here any definition of it. It is one of the three component parts of milk, the other two being *whey* and *cheeſe.* It is evident from the proceſſes by which butter and cheeſe are made, that theſe two parts are not completely diſſolved in the ſerum or whey, but only diffuſed through it like an emulſion. They may indeed be ſeparated from it by reſt alone, without any artificial preparation.

Butter, though uſed at preſent as food in moſt countries of Europe, was not known, or known very imperfectly, to the ancients. This, we think, is completely proved by Profeſſor Beckmann in the ſecond volume of his *Hiſtory of Inventions.* In our tranſlation of the Hebrew Scripture, there is indeed frequent mention made of butter at very early periods; but, as the Profeſſor well obſerves, the greateſt maſters of biblical criticiſm unanimouſly agree, that the word ſo tranſlated ſignifies milk or cream, or ſour thick milk, and cannot poſſibly mean what we call *butter.* The word plainly alludes to ſomething liquid which was uſed for waſhing the feet, which was drunk, and which had ſometimes the power of intoxicating; and we know that mare's milk may be ſo prepared as to produce the ſame effect. See Koumiss, *Encycl.*

The oldeſt mention of butter, the Profeſſor thinks, is in the account of the Scythians given by Herodotus (lib. iv. 2.), who ſays, that "theſe people pour the milk of their mares into wooden veſſels, cauſe it to be violently ſtirred or ſhaken by their blind ſlaves, and ſeparate the part which ariſes to the ſurface, as they conſider it as more valuable and delicious than what is collected below it." That this ſubſtance muſt have been a ſoft kind of butter, is well known; and Hippocrates gives a ſimilar account of Scythian butter, and calls it πικεριον, which Galen tranſlates by the word βουτυρον. The poet Anaxandrides, who lived ſoon after Hippocrates, deſcribing the marriage feaſt of Iphicrates, who married the daughter of Cotys king of Thrace, ſays, that the Thracians ate butter, which the Greeks at that time conſidered as a wonderful kind of food.

Dioſcorides ſays, that good butter was prepared from the fatteſt milk, ſuch as that of ſheep or goats, by ſhaking it in a veſſel till the fat was ſeparated. To this butter he aſcribes the ſame effects, when uſed externally, as thoſe produced by our butter at preſent. He adds alſo, and he is the firſt writer who makes the obſervation, that freſh butter might be melted and poured over pulſe and vegetables inſtead of oil, and that it might be employed in paſtry in the room of other fat ſubſtances. A kind of ſoot likewiſe was at that time prepared from butter for external applications, which was uſed in curing inflammation of the eyes and other diſorders. For this purpoſe the butter was put into a lamp, and when conſumed the lamp was again filled till the deſired quantity of ſoot was collected in a veſſel placed over it.

Galen, who diſtinguiſhes and confirms in a more accurate manner the healing virtues of butter, expreſsly remarks, that cow's milk produces the fatteſt butter; that butter made from ſheep's or goat's milk is leſs rich; and that aſs's milk yields the pooreſt. He expreſſes his aſtoniſhment, therefore, that Dioſcorides ſhould ſay that butter was made from the milk of ſheep and goats. He aſſures us that he had ſeen it made from cow's milk, and that he believes it had thence acquired its name. "Butter (ſays he) may be very properly employed for ointments; and when leather is beſmeared with it, the ſame purpoſe is anſwered as when it is rubbed over with oil. In cold countries, which do not produce oil, butter is uſed in the baths; and that it is a real fat, may be readily perceived by its catching fire when poured over burning coals." What has been here ſaid is ſufficient to ſhew that butter muſt have been very little known to or uſed by the Greeks and the Romans in the time of Galen, that is, at the end of the ſecond century.

The Profeſſor having collected, in chronological order, every thing which he could find in the works of the ancients reſpecting butter, concludes, that it is not a Grecian, and much leſs a Roman, invention, but that the Greeks were made acquainted with it by the Scythians, the Thracians, and the Phrygians, and the Romans by the people of Germany. He is likewiſe decidedly of opinion, that when theſe two poliſhed nations had learned the art of making it, they uſed it not as food, but only as an ointment, or ſometimes as a medicine. "We never find it (ſays he) mentioned by Galen and others as a food, though they have ſpoken of it as applicable to other purpoſes. No notice is taken of it by Apicius; nor is there any thing ſaid of it in that reſpect by the authors who treat on agriculture, though they have given us very particular information concerning milk, cheeſe, and oil."

The caſe, however, is now very different. It is, in this country at leaſt, ſo general an article of food, that the proper methods of making and curing it have engaged the attention of ſome of our ableſt writers on agriculture. In addition to what has been ſaid on theſe ſubjects under the titles Butter and Dairy (*Encyclopædia*), our readers will probably be pleaſed with the following method of curing it, which is practiſed by ſome farmers in the pariſh of Udney, in the county of Aberdeen, and gives to their butter a great ſuperiority above that of their neighbours.

Take two parts of the beſt common ſalt, one part of ſugar, and one part of ſaltpetre; beat them up together, and blend the whole completely. Take one ounce of this compoſition for every ſixteen ounces of butter, work it well into the maſs, and cloſe it up for uſe.

Dr James Anderſon, from whoſe View of the Agriculture of the County of Aberdeen this receipt is taken, ſays, that he knows of no ſimple improvement in economics greater than this is, when compared with the uſual mode of curing butter by means of common ſalt alone. "I have ſeen (continues he) the experiment fairly made, of one part of the butter made at one time being thus cured, and the other part cured with ſalt alone: the difference was inconceivable. I ſhould ſuppoſe that, in any open market, the one would ſell for 30 *per cent*, more than the other. The butter cured with the mixture appears of a rich marrowy conſiſtence and fine colour, and never acquires a brittle hardneſs nor taſtes ſalt; the other is comparatively hard and brittle, approaching more nearly to the appearance of tallow, and is much ſalter to the taſte. I have ate butter cured with the above compoſition that had been kept three years, and it was as ſweet as at firſt; but it muſt be noted, that butter thus cured requires to ſtand three weeks or a month before it is begun to be uſed. If it be ſooner opened, the ſalts are not ſufficiently blended with it; and ſometimes the coolneſs of the nitre will then be perceived, which totally diſappears afterwards."

The following obſervations reſpecting the proper method of keeping both milk and butter are by the ſame author, and we truſt may prove uſeful. Speaking ſtill of the county of Aberdeen, he ſays, "The pernicious practice of keeping milk in leaden veſſels, and ſalting butter in ſtone jars, begins to gain ground among ſome of the fine ladies in this county, as well as elſewhere, from an idea of cleanlineſs. The fact is, it is juſt the reverſe of cleanlineſs; for in the hands of a careful perſon nothing can be more cleanly than wooden diſhes, but under the management of a ſlattern they diſcover the ſecret which ſtone diſhes indeed do not.

"In return, theſe latter communicate to the butter and the milk, which has been kept in them, a poiſonous quality, which inevitably proves deſtructive to the human conſtitution. To the prevalence of this practice I have no doubt we muſt attribute the frequency of palſies, which begin to prevail ſo much in this kingdom; for the well known effect of the poiſon of lead is bodily debility, palſy—death!"

BUTTERHILL, a high round hill, on the W. bank of Hudſon river, at the northern entrance of the Highlands. In paſſing this hill, aſcending the river, the paſſenger is preſented with a charming view of New-Windſor and Newburgh.—*Morſe.*

BUXTON, a townſhip in York co. diſtrict of Maine, ſituated on Saco River; 16 miles N. weſterly from Pepperelborough, at the mouth of that river, and 118 miles N. E. of Boſton; containing 1564 inhabitants. —*ib.*

BYEFIELD, a pariſh in Newbury, Eſſex co. Maſſachuſetts. In a quarry of lime ſtone here, is found the *aſbeſtos*, or incorruptible cotton, as it is ſometimes called. Beautifully variegated marble, which admits a good poliſh, has likewiſe been found in the ſame vicinity. Here is alſo a flouriſhing woollen manufactory eſtabliſhed on a liberal ſcale ; and machinery for cutting nails.—*ib.*

BYRD, FORT, lies on the eaſtern bank of Monongahela River; on the S. ſide of the mouth of Red-Stone Creek ; 35 miles S. from Pittſburg, and about 29 N. W. from Ohiopyle Falls. On or near this ſpot ſtands the compact part of the town of Brownſville. N. lat. 39. 58. W. long. 81. 12.—*ib.*

BYSAK, the firſt month of the Bengal year, beginning in April.

C.

CABARRUS, a new county in the diſtrict of Saliſbury, North-Carolina.—*Morse.*

CABIN *Point*, a ſmall poſt-town in Surry co. Virginia, ſituated on Upper Chipoak creek, 26 miles E. S. E. of Peterſburg, 87 from Portſmouth, and 329 S. S. W. of Philadelphia. N. lat. 37.—*ib.*

CACAPEHON, a river of Virginia, which runs about 70 miles N. eaſterly along the weſtern ſide of North Ridge, and empties into Potowmack River, 30 miles N. from Frederickſtown.—*ib.*

CADIZ, a town on the N. ſide of the iſland of Cuba, near 160 miles E. of Havannah, and 50 N. from Spiritu Santo.—*ib.*

CÆSARIA *River*, or *Cohanſie Creek*, in New-Jerſey, empties into Delaware Bay, after a S. weſterly courſe of about 30 miles. It is navigable for veſſels of 100 tons as far as Bridgetown, 20 miles from its mouth.—*ib.*

CAFFRES, the inhabitants of Caffraria, are generally confounded with the Hottentots ; but, according to M. Vaillant, there is a conſiderable difference between the manners, cuſtoms, and even appearance of theſe two nations.

The Caffres, ſays he, are generally taller than the Hottentots, more robuſt, more fierce, and much bolder. Their figure is likewiſe more agreeable, and their countenances have not that narrowneſs at the bottom, nor their cheeks thoſe prominences, which are ſo diſagreeable among the Hottentots. A round figure, a noſe not too flat, a broad forehead, and large eyes, give them an open and lively air ; and if prejudice can overlook the colour of the ſkin, there are ſome Caffre women who, even in Europe, would be accounted pretty. Theſe people do not make their faces ridiculous, by pulling out their eye-brows like the Hottentots ; they tattoo themſelves much, and particularly their bodies ; their hair, which is frizzled very much, is never greaſed, but their bodies are liberally anointed, merely with a view to preſerve their vigour and agility.

The men generally beſtow more attention on their dreſs than the women, and are remarkably fond of beads and copper rings. The women wear hardly any of the ornaments in which the other ſavages in Africa take ſuch delight. They do not even wear copper bracelets ; but their ſmall aprons, which are ſtill ſhorter than thoſe of the Hottentots, are bordered with a few rows of glaſs-beads ; and in this all their luxury conſiſts. It would appear that the Caffres are not ſo chaſte as the Hottentots, becauſe the men do not uſe a jackal to vail what nature teaches other men, even ſavages, to conceal. A ſmall cowl, which covers only the glans, inſtead of diſplaying modeſty, ſeems to announce the greateſt indecency. This ſmall covering adheres to a thong, which is faſtened round their girdles, merely that it may not be loſt; for a Caffre, if he be not afraid of being hurt or ſtung by inſects, cares very little whether his cowl be in its place or not. Our author ſaw one Caffre, who, inſtead of a cowl, wore a caſe made of wood, and ornamented with ſculpture. This was a new and ridiculous faſhion, which he had borrowed from a nation of black people who lived at a great diſtance from Caffraria.

In the hot ſeaſon the Caffres go always naked, and retain nothing but their ornaments. In cold weather they wear kroſſes made of calves or oxen's hides, which reach down to the ground ; but whatever the weather be, both ſexes go bare-headed, except that they ſometimes, though rarely, fix a plume of feathers in their hair.

The Caffre huts are more ſpacious and higher than thoſe of the Hottentots, and have alſo a more regular form. The frames of them are conſtructed of wooden work, well put together, and very ſolid, being intended to laſt for a long time : for the Caffres, applying to agriculture, which the free Hottentots do not, remain fixed to one ſpot, unleſs ſomething unexpected interrupt their repoſe.

A more perceptible induſtry, an acquaintance with ſome of the moſt neceſſary arts of life, a little knowledge of agriculture, and a few religious dogmas, ſeem to announce that the Caffres approach much nearer to civilization than the Hottentots. They entertain a tolerably exalted idea of the Supreme Being and his power ; they believe that the good will be rewarded, and the wicked puniſhed, in a future ſtate ; but they have no notion of creation, which indeed was not admitted by the ſages of Greece and Rome. They practiſe circumciſion, but can give no account of its origin among them, or of the purpoſe for which the practice is continued.

Polygamy is uſed among the Caffres ; and on the death of a father the male children and their mothers ſhare the ſucceſſion among them. The girls remain with their mothers without property of any kind until they can procure huſbands. One very ſingular cuſtom of the Caffres is, that they do not, in general, inter their dead, but tranſport them from the kraal to an open ditch, which is common to the whole horde. At this ditch ſavage animals feed at their leiſure on the multitude of carcaſes which are heaped together. Funeral honours are due only to kings and the chiefs of each horde, whoſe bodies are covered with a heap of ſtones collected into the form of a dome.

This nation is governed by a general, chief, or king, whoſe power is very limited. He appoints, however, the ſubordinate chiefs over the different hordes, and through them communicates his directions or orders. The arms of the Caffre are a *club,* two feet and a half in length, and where thickeſt three inches in diameter, and a plain lance or *aſſagey.* He deſpiſes poiſoned arrows, which are ſo much uſed by ſome of the neighbouring nations; and with his two ſimple weapons ſeeks always to meet his enemy face to face in the field. The Hottentot, on the contrary, concealed under a rock or behind a buſh, deals out deſtruction, without being expoſed to danger. The one is a perfidious tyger, which ruſhes treacherouſly on his prey; the other is a generous lion, which, having given warning of his approach, makes his attack boldly, and periſhes if he prevail not againſt his antagoniſt.

CAGHNEWAGA, a tribe of Indians in Lower Canada, ſome of whom inhabit near Montreal.—*Morse.*

CALCAYLARES, a juriſdiction in S. America, and empire of Peru, ſubject to the biſhop of Cuſco, about 4 leagues W. of that city; exuberant in all kinds of grain and fruits, and ſugar equal to any of the refined ſugar of Europe. Formerly it produced 80,000 arobas; but the quantity is now ſaid to be much leſs. —*ib.*

CALCULUS, in mathematics, denotes a certain way of performing inveſtigations and reſolutions, which occur on many occaſions, particularly in mechanical philoſophy. Thus we ſay, the *antecedental* calculus, the *algebraical* calculus, the *arithmetical* calculus, the *differential* calculus, the *exponential* calculus, the *fluxional* calculus, and the *integral* calculus. Of by much the greater part of theſe calculi ſome account has been given in the Encyclopædia; but there is one of them, of which no notice has been taken in that work. It is,

The Antecedental CALCULUS, a geometrical method of reaſoning, without any conſideration of motion or velocity, applicable to every purpoſe to which the much celebrated doctrine of fluxions of the illuſtrious Newton has been, or can be, applied. This method was invented by James Glenie, Eſq; "in which (he ſays) every expreſſion is truly and ſtrictly geometrical, is founded on principles frequently made uſe of by the ancient geometers, principles admitted into the very firſt elements of geometry, and repeatedly uſed by EUCLID himſelf. As it is a branch of general geometrical proportion, or univerſal compariſon, and is derived from an examination of the antecedents of ratios, having given conſequents and a given ſtandard of compariſon in the various degrees of augmentation and diminution they undergo by compoſition and decompoſition, I have called it the antecedental calculus. As it is purely geometrical, and perfectly ſcientific, I have, ſince it firſt occurred to me in 1779, always made uſe of it inſtead of the fluxionary and differential calculi, which are merely arithmetical. Its principles are totally unconnected with the ideas of motion and time, which, ſtrictly ſpeaking, are foreign to pure geometry and abſtract ſcience, though, in mixed mathematics and natural philoſophy, they are equally applicable to every inveſtigation, involving the conſideration of either with the two numerical methods juſt mentioned. And as many ſuch inveſtigations require compoſitions and decompoſitions of ratios, extending greatly beyond the triplicate and ſubtriplicate, this calculus in all of them furniſhes every expreſſion in a ſtrictly geometrical form. The ſtandards of compariſon in it may be any magnitudes whatever, and are of courſe indefinite and innumerable; and the conſequents of the ratios, compounded or decompounded, may be either equal or unequal, homogeneous or heterogeneous. In the fluxionary and differential methods, on the other hand, 1, or unit, is not only the ſtandard of compariſon, but alſo the conſequent of every ratio compounded or decompounded."

This method is deduced immediately from Mr Glenie's Treatiſe on the Doctrine of Univerſal Compariſon or General Proportion: And as the limits of the preſent work will not allow us to enter upon this ſubject, we therefore refer our readers to the two above mentioned treatiſes, and to the fourth volume of the Tranſactions of the Royal Society of Edinburgh.

We confeſs, however, that we do not expect ſuch great advantage from the employment of this calculus as the very acute and ingenious author ſeems to promiſe from it. The mathematical world is truly indebted to him for the clear and diſcriminating view that he has taken of the doctrine of univerſal compariſon, and we believe it to be perfectly accurate, and in ſome reſpects new. Notwithſtanding the continual occupation of mathematicians with ratios and analogies, their particular objects commonly reſtricted their manner of conceiving ratio to ſome preſent modification of it. Hence it ſeems to have happened that their conceptions of it as a magnitude have not been uniform. But Mr Glenie, by avoiding every peculiarity, has at once attributed to it all the meaſurable affections of magnitude, addition or ſubtraction, multiplication or diviſion, and ratio or proportion. He is perhaps the firſt who has roundly conſidered ratio or proportion as an affection of ratio; and it is chiefly by the employment of this undoubted affection of ratio that he has rendered the geometrical analyſis ſo comprehenſive.

But when we view this antecedental calculus, not as a method of expreſſing mathematical ſcience, but as an art, as a calculus in ſhort, and conſider the means which it muſt employ, and the notations which muſt be uſed, we become leſs ſanguine in our hopes of advantage from it. The notation cannot (we think) be more ſimple than that of the fluxionary method, juſtly called *arithmetical;* and if we inſiſt on carrying clear conceptions along with us, we imagine that the arithmetical expoſition of our ſymbols will generally be the ſimpler of the two. The *ſcience* of the antecedental calculus ſeems to conſiſt in the attainable perception of all the ſimple ratios, whether of *magnitudes,* or *ratios,* or both, which concur to the formation of a compound and complicated ratio. Now this is equally, and more eaſily, attainable in the fluxionary or other arithmetical method, when the conſequent is a ſimple magnitude. When it is not, the ſame proceſs is farther neceſſary in both methods, for getting rid of its complication.

We apprehend that it is a miſtake that the geometrical method is more abſtracted than the fluxionary, becauſe the latter ſuperadds to the notion of extenſion the notions of time and motion. Theſe notions were introduced by the illuſtrious inventor *for the demonſtration*, but never occupy the thoughts *in the uſe* of his propoſitions. Theſe are *geometrical* truths, no matter how demonſtrated; and when duly conſidered, involve nothing that is omitted in the antecedental calculus. We even preſume to ſay, that the complication of thought, in the contemplation of the ratios of ratios, is greater than what will generally ariſe from the additional elements, time and motion.

We do not find that any of our moſt active mathematicians have availed themſelves of the advantages of this calculus, nor do we know any ſpecimen that has been exhibited of its eminent advantages in mathematical diſcuſſions. Should it prove more fertile in geometrical expreſſions of highly compounded or complicated quantities or relations, we ſhould think it a mighty acquiſition; being fully convinced that theſe afford to the memory or imagination an object (we may call it a ſenſible picture) which it can contemplate and remember with incomparably greater clearneſs and ſteadineſs than any algebraical formula. We need only appeal to the geometrical expreſſions of many fluents, which are to be ſeen in Newton's lunar theory, in the phyſical tracts of Dr Matthew Stewart, and others who have ſhewn a partiality for this method.

It would be very preſumptuous, however, for us to ſay, that the accurate geometer and metaphyſician may not derive great advantages from proſecuting the very ingenious and recondite ſpeculations of Mr Glenie, in his doctrine of univerſal compariſon.

CALEDONIA *Co.* in Vermont, contains 24 townſhips and has Connecticut river S. E.; Orleans and Chittenden counties N. W.; Eſſex co. N. E.; and Orange co. of which, until lately, it formed a part, S. W.—*Morse.*

Caledonia, a port on the iſthmus of Darien, in the N. Sea, 25 leagues N. W. from the river Atrato. It was attempted to be eſtabliſhed by the Scotch nation in 1698, and had at firſt all the promiſing appearances of ſucceſs; but the Engliſh, influenced by narrow national prejudices, put every impediment in their way; which, joined to the unhealthineſs of the climate, deſtroyed the infant colony.—*ib.*

CALENDAR, in chronology. See *(Encycl.)* Kalendar; and Revolution, n° 184.

CALI, a city of New Granada, S. America, ſituated on the river Cauca. The ſtaple port for this city, as alſo for thoſe of Popayan, Santa Fe, and the ſouthern parts of Terra Firma, is Bonaventura in the diſtrict of Popayan. The road by land from that port is not paſſable for beaſts of burden; ſo that travellers, with their baggage, are carried on the backs of Indians in a chair, with which weight they croſs rivers and mountains, being entirely ſlaves to the Spaniards, who thus ſubſtitute them in the room of horſes and mules. N. lat. 3. 15. W. long. 76. 30.—*Morse.*

CALIPPIC period, in chronology, a period of 76 years, continually recurring; at every repetition of which, it was ſuppoſed by its inventor Calippus, an Athenian aſtronomer, that the mean new and full moons would always return to the ſame day and hour.

About a century before, the golden number, or cycle of 19 years, had been invented by Meton; which Calippus finding to contain 19 of Nabonaſſar's year, 4 days, and $\frac{331}{459}$, to avoid fractions he quadrupled it, and ſo produced his period of 76 years, or 4 times 19; after which he ſuppoſed all the lunations, &c. would regularly return to the ſame hour. But neither is this exact, as it brings them too late by a whole day in 225 years.

CALLAO, as it is called by its inhabitants, but more generally known to Europeans under the name of Campello, is a ſmall iſland, which was viſited by ſome of Lord Macartney's ſuite on their voyage to China. In conſequence of that viſit, we have the following deſcription of it in Sir George Staunton's Account of the Embaſſy.

"It lies oppoſite to, and about eight miles to the eaſtward of, the mouth of a conſiderable river on the coaſt of Cochin-china, on the banks of which is ſituated the town of Fai-foo, a place of ſome note, not far from the harbour of Turon. The bearing of the higheſt peak of Callao from this harbour is about ſouth-eaſt, diſtance thirty miles. The extreme points of the iſland lie in latitude 15° 53′, and 15° 57′ north; the greateſt length is from north-weſt to ſouth-eaſt, and is ſomewhat about five miles, and the mean breadth two miles. The only inhabited part is on the ſouth-weſt coaſt, on a ſlip of ground riſing gently to the eaſt, and contained between the bottom of a ſemilunar bay and the mountains on each ſide of it. Thoſe mountains, at a diſtance, appear as if they formed two diſtinct iſlands. The ſouthern mountain is the higheſt, and is about 1500 feet. The lower grounds contain about 200 acres. This ſmall but enchanting ſpot is beautifully diverſified with neat houſes, temples, clumps of trees, ſmall hillocks ſwelling from the plain, and richly decorated with ſhrubbery and trees of various kinds; among which the elegant areca, riſing like a Corinthian column, is eminently conſpicuous. A rill of clear water, oozing from the mountains, is contrived to be carried along the upper ridges of the vale, from whence it is occaſionally conveyed through ſluices, for the purpoſe of watering the rice grounds, and appeared, though then in the dry ſeaſon, fully ſufficient for every purpoſe for which it could be wanted.

"The houſes, in general, were clean and decent; a few were built with ſtone, and covered with tiles. One, probably the manſion of the chief perſon of the iſland, was incloſed by a ſtone wall, and the approach to it was through a gateway between two ſtone pillars. The houſe was divided into a number of apartments, of which the arrangement did not ſeem to want either taſte or convenience. This building ſtood at the head of the principal village, which conſiſted of about thirty habitations built of wood, chiefly the bamboo. Behind the village, and on the ſide of the hill, was a cave, acceſſible only by one way, through an irregular range of rocks. Within the cave, but near its mouth, was a ſmall temple, commanding a view of the whole vale. Several other temples were diſperſed over the plain, all of which were open in front, with a colonnade before them of round wooden pillars, painted red and varniſhed. The number of houſes on the iſland ſcarcely exceeded ſixty. Behind every houſe, not immediately in the principal village, were incloſures of ſugar-canes, tobacco, and other vegetables, growing in great luxuriance. The mountains were covered with verdure, and ſeemed well calculated for rearing goats, of which the iſland produced a few.

"Beſide the principal bay, there were ſeveral ſandy inlets, with ſmall patches of level ground behind them. Boats might eaſily land in any of theſe inlets; but a communication between them by land appeared to be exceedingly difficult, if not entirely prevented, by the ſteep and rugged ridges which ſeparated them from each other. On this account very ſlight works, and an eſtabliſhment of a few men only, would be requiſite for the defence of the iſland, a great part of its coaſt being impregnably fortified by nature. The depth of water in the bay and road was ſufficient for ſhips of any burden, and there was perfect ſhelter from every wind except the ſouth-weſt, to which quarter it was directly open. The ſhort diſtance however, from the continent in that direction would always prevent the ſea from riſing high, though it might not be ſufficiently near to break the force of the wind."

The inhabitants of this iſland are ſo exceedingly ſhy and afraid of ſtrangers, that upon the approach of the Engliſh veſſel, they all, except a very few, retired on board their galleys. When the Britiſh landed, therefore, they found the doors of all the houſes open, with ſeveral domeſtic animals feeding before them, but neither man, woman, nor child within. After ſome time, however, a perſon was perceived lurking among the neighbouring trees, who, finding he was obſerved, came forward with reluctance and evident marks of fear. While he was yet at ſome diſtance, he fell upon his knees, and touched the ground with his forehead ſeveral times. On approaching to him, it was noticed that the firſt joint of every one of his fingers and toes was wanting, and as if twiſted off by violence; it was poſſible that he might have thus been treated by way of puniſhment for ſome crime, and that he was conſidered as the fitteſt perſon to be expoſed to the ſuppoſed danger of watching the movements of the ſtrangers coming aſhore. In a little time ſome others, hidden in the thickets, finding that no miſchief was ſuffered by the firſt, ventured out. None of them could underſtand the Chineſe interpreter; and not being able to read or write, there was no converſing with them by the medium of the Chineſe characters. Recourſe was had to hieroglyphics, and rude figures were drawn of the articles which were propoſed to be purchaſed; and this method ſucceeded tolerably well; poultry and fruits were brought for ſale, for which high prices were given, purpoſely to conciliate the good will of thoſe iſlanders. The few that were found grew ſoon familiar; and one old man preſſingly invited the ſtrangers to his houſe, ſituated upon an eminence, at a little diſtance. On arriving there, he introduced them to his wife, an old woman, who, after recovering from her aſtoniſhment at the ſight of figures ſo different from thoſe ſhe had ever been accuſtomed to behold, laid, in a neat manner, before them ſome fruits, ſugar, cakes, and water. On departing from the houſe, this decent and hoſpitable couple made ſigns to teſtify their deſire of ſeeing them again."

The poſſeſſion of this iſland would be of ſuch importance to any European nation who wiſhed to trade ſecurely with TUNG-QUIN and COCHIN-CHINA, that it is ſaid the French had formerly ſome thoughts of purchaſing it. Sir George Staunton, however, is of opinion, that the want of ſhelter in the ſouth-weſt monſoon would render it of little value, without a further ſettlement near it upon the main land of Cochin-china; and he thinks, that if a ſolid eſtabliſhment there could be productive of advantage to any European nation, it would neceſſarily be ſo to Great Britain; becauſe, beſide the opening which it would make for the ſale of Britiſh manufactures among the people of the country, the Britiſh poſſeſſions in Hindoſtan would be ſure of a very conſiderable demand for their productions.

CALLAO, a ſea-port town in the empire of Peru, being the port or harbor of Lima, and is ſituated 2 leagues from that city. On the N. ſide runs the river which waters Lima, on which ſide is a ſmall ſuburb built only of reeds. There is another on the S. ſide; they are both called Pitipiſti, and inhabited by Indians. To the E. are extenſive plains, adorned with beautiful orchards watered by canals cut from the river. The town, which is built on a low flat point of land, was ſtrongly fortified in the reign of Philip IV.; and numerous batteries command the port and road, which is the greateſt, fineſt, and ſafeſt in all the South Sea. There is anchorage every where in very deep water, without danger of rocks or ſhoals, except one, which is 3 cables-length from the ſhore, about the middle of the iſland of St Lawrence, oppoſite La Galatea. The little iſland of Callao lies juſt before the town. In the opening between theſe two iſlands, there are two ſmall iſlots, or rather rocks; there is alſo a third very low, but half a league out at ſea, S. S. E. from the N. W. point of the iſland of St. Lawrence. Near the ſea-ſide is the governor's houſe, which, with the viceroy's palace, take up two ſides of a ſquare; the pariſh church makes a third; and a battery of 3 pieces of cannon forms the fourth. The churches are built of canes interwoven, and covered with clay, or painted white. Here are 5 monaſteries, and an hoſpital. The houſes are in general built of ſlight materials; the ſingular circumſtance of its never raining in this country, renders ſtone houſes unneceſſary; and beſides, theſe are more apt to ſuffer from earthquakes, which are frequent here. The moſt remarkable happened in the year 1746, which laid ¾ths of Lima level with the ground, and entirely demoliſhed Callao; where the deſtruction was ſo entire that only one man, of 3000 inhabitants, was left to record this dreadful calamity. S. lat. 12. 1. W. long. 77.—*Morſe.*

CALOS, a bay on the W. coaſt of the peninſula of E. Florida, where are excellent fiſhing banks and grounds. Not far from this is a conſiderable town of Seminole Indians. The Spaniards from Cuba take great quantities of fiſh here, and barter with the Indians and traders for ſkins, furs, &c. and return with their cargoes to Cuba.—*ib.*

CAMBRIDGE, a townſhip in Grafton co. New-Hampſhire, E. of Androſcoggin, and S. of Umbagog Lake.—*ib.*

Cambridge, a townſhip in Waſhington co. New-York. By the cenſus of 1790, it contained 4996 inhabitants, including 41 ſlaves. By the ſtate cenſus of 1796, it appears there are 623 electors.—*ib.*

Cambridge, the half ſhire town of Middleſex co.

Maſſachuſetts, is one of the largeſt and moſt reſpectable townſhips of the county. Its 3 pariſhes, Cambridge, Little Cambridge, and Menotomy, contain 3 Congregational meeting houſes, one for Baptiſts, and another for Epiſcopalians; a number of very pleaſant ſeats, and 2115 inhabitants. The elegant bridge which connects this town with Boſton has been deſcribed under the head of Boſton. The compact part of Cambridge is pleaſantly ſituated 3½ miles weſtward of Boſton, on the N. bank of Charles river, over which is a bridge leading to Little Cambridge. It contains about 100 dwelling houſes. Its public buildings, beſides the edifices which belong to Harvard univerſity, are the Epiſcopal and Congregational meeting-houſes, and a handſome court-houſe. The college buildings are 4 in number, and are of brick, named Harvard, Hollis, and Maſſachuſetts Halls, and Holden Chapel. They ſtand on a beautiful green which ſpreads to the N. W. and exhibit a pleaſing view. This univerſity, as to its library, philoſophical apparatus and profeſſorſhips, is at preſent the firſt literary inſtitution on this continent. It takes its date from the year 1638, 7 years after the firſt ſettlement in the townſhip, then called *Newtown.* Since its eſtabliſhment, to July 1794, 3399 ſtudents have received honorary degrees from its ſucceſſive officers. It has generally from 140 to 200 ſtudents. The library contains upwards of 12000 volumes. The cabinet of minerals, in the muſeum, contains the more uſeful productions of nature; and excepting what are called the *precious ſtones,* there are very few ſubſtances yet diſcovered in the mineral kingdom, but what may be found here. The univerſity owes this noble collection of minerals, and ſeveral other natural curioſities, to the munificence of Dr. Lettſom, of London, and to that of the republic of France. N. lat. 42. 23. 28. W. long. from Greenwich 71. 7. 30. —*ib.*

CAMBRIDGE, a poſt town of Ninety-Six diſtrict, in the upper country of S. Carolina, where the circuit courts are held. It contains about 60 houſes, a court-houſe and a brick gaol. The college by law inſtituted here is no better than a grammar ſchool. It is 80 miles N. N. W. of Columbia; 50 N by W. of Auguſta, in Georgia, 140 N. W. of Charleſton, and 762 S. W. of Philadelphia. N. lat. 34. 9.—*ib.*

CAMBRIDGE, the chief town of Dorcheſter co. Maryland, is ſituated on the S. ſide of Choptank River, about 13 miles E. S. E. from Cook's point at its mouth; 9 W. S. W. from Newmarket, and 57 S. E. from Baltimore. Its ſituation is healthy, and it contains about 50 houſes and a church. N. lat. 38. 34.—*ib.*

CAMBRIDGE, in Franklin co. Vermont, is ſituated on both ſides of La Moille River, about 20 miles W. of Lake Champlain and has 359 inhabitants.—*ib.*

CAMDEN *Co.* in Edenton diſtrict, N. Carolina, is in the N. E. corner of the ſtate. It has 4033 inhabitants, including 1038 ſlaves. Joneſborough is the chief town.—*ib.*

CAMDEN, *Diſtrict,* in the upper country of S. Carolina, has Cheraws diſtrict on the N. E. Georgetown diſtrict on the S. E. and the ſtate of N. Carolina on the N.; and is divided into the following counties, Fairfield, Richland, Clarendon, Claremont, Kerſhaw, Salem and Lancaſter. It is 82 miles from N. to S. and 60 from E. to W. and contain 38,265 inhabitants, including 8865 ſlaves. This diſtrict is watered by the Wateree, or Catabaw River and its branches; the upper part is variegated with hills, generally fertile and well watered. It produces Indian corn, wheat, rye, barley, tobacco, and cotton. The Catabaw Indians, the only tribe which reſide in the ſtate, live in the N. part of this diſtrict.—*ib.*

CAMDEN, a poſt town, and chief of Camden diſtrict, S. Carolina, in Kerſhaw co. ſtands on the E. ſide of Wateree River; 35 miles N. E. of Columbia; 55 S. W. of Cheraw; 120 N. by W. of Charleſton, and 643 S. W. of Philadelphia. It is regularly laid out, and contains about 120 houſes, an Epiſcopal church, a court-houſe and gaol. The navigable river on which the town ſtands, enables the inhabitants to carry on a lively trade with the back country. N. lat. 34. 12. W. long. 80. 54.

This town, or near it, was the ſcene of two battles in the late war. On the 16th of Auguſt, 1780, between Gen. Gates and Lord Cornwallis, in which the American general was defeated. The other was a briſk action between Lord Rawdon and Gen. Green, on the 25th of April, 1781. Lord Rawdon ſallied out of the town with 800 men, and attacked the American camp, which was within a mile of the town. The Americans had 126 men killed, and 100 taken priſoners, and the Britiſh had about 100 killed. The town was evacuated the 9th of May, in the ſame year, after Lord Rawdon had burned the gaol, mills, many private houſes, and part of his own baggage.—*ib.*

CAMDEN *Co.* in the lower diſtrict of Georgia, at the S. E. corner of the ſtate, on St Mary's River, contains 305 inhabitants, including 70 ſlaves. Chief town St Patricks.—*ib.*

CAMDEN, a ſmall poſt town on the weſtern ſide of Penobſcot bay, diſtrict of Maine, and the S. eaſternmoſt townſhip of Lincoln co. having Thomaſtown on the S. W.; 35 miles N. N. E. from Pownalborough, and 228 miles N. E. from Boſton.—*ib.*

CAMDEN, a village in Kent co. ſtate of Delaware; about 4 miles S. W. from Dover, and 5 N. weſterly from Frederica.—*ib.*

CAMEL, in navigation, is a machine which has been deſcribed with ſufficient accuracy in the Encyclopædia; but the following account of its invention, given by Profeſſor Beckmann, is perhaps not unworthy of a place in this Supplement.

“ In the Zuyder-Zee, oppoſite to the mouth of the river Y, about ſix miles from the city of Amſterdam, there are two ſand banks, between which is a paſſage called the *Pampus,* which is ſufficiently deep for ſmall ſhips, but not for ſuch as are large or heavy laden. In 1672 the Dutch contrived, however, to carry their numerous fleet through this paſſage, by means of large empty cheſts faſtened to the bottom of each ſhip; and this contrivance gave riſe to the invention of the *camel.*” In the Encyclopædia its invention is given to the famous De Wit; in the German Cyclopædia to Meyer a Dutch engineer of very conſiderable eminence; but the Dutch writers, almoſt unanimouſly, aſcribe the invention of the camel to a citizen of Amſterdam, who calls himſelf Meeuves Meindertſon Bakker. “ Some make the year of the invention to have been 1688, and others 1690. Much has been ſaid of the utility of this invention; but however beneficial it may be, we have reaſon to ſuppoſe that ſuch heavy veſſels as ſhips of war cannot be raiſed up, in ſo violent a manner, without ſuſtaining injury. A ſure proof of this is the well known circumſtance mentioned by Muſchenbroek (*Introductio ad Philoſoph. Natur.*), that the ports of a ſhip which had been raiſed by the camel could not afterwards be ſhut cloſely."

CAMELEON, one of the conſtellations of the ſouthern hemiſphere, near the ſouth pole, and inviſible in our latitude. There are 10 ſtars marked in this conſtellation in Sharp's catalogue.

CAMELOPARDALUS, a new conſtellation of the northern hemiſphere, formed by Hevelius, conſiſting of 32 ſtars, firſt obſerved by him. It is ſituated between Cepheus, Caſſiopeia, Perſeus, the Two Bears, and Draco; and it contains 58 ſtars in the Britiſh catalogue.

CAMELLIA, in botany (ſee *Encycl.*), is a plant which the Chineſe call *Cha wha*, or flower of tea, on account of the reſemblance of the one to the other, and becauſe its petals are ſometimes mixed among the teas to increaſe their fragrance. Sir George Staunton, who calls it *Camellia Seſanqua*, ſaw it flouriſhing on the ſides and very high tops of mountains, where the ſoil conſiſted of little more than fragments of ſtone, crumbled into a ſort of coarſe earth by the joint action of the ſun and rain. It yields, he ſays, a nut, from which is expreſſed an eſculent oil, equal to the beſt which comes from Florence. On this account, it is cultivated in vaſt abundance; and is particularly valuable from the facility of its culture in ſituations fit for little elſe.

CAMPBELL (George, D. D.), ſo juſtly admired for his metaphyſical acuteneſs and various erudition, was, in 1719, born at Aberdeen, where his father, the reverend Colin Campbell, was one of the miniſters of the eſtabliſhed church. He was educated in his native city; and, after paſſing through the uſual courſe of academical learning, he ſtudied divinity under the Rev. J. Chalmers, profeſſor of divinity in Mariſchal College.—He was, in 1749, an unſucceſsful candidate for the church of Fordown, though his competitor Mr Forbes was a man of very ſlender abilities, and ſuppoſed to be attached to the conſtitution and liturgy of the church of England. It might indeed be that attachment which contributed principally to procure him the living in preference to Mr Campbell.

The living of Fordown is in the gift of the crown; and it has generally been a rule with his majeſty's miniſters, to give ſuch livings, when they become vacant, to thoſe candidates who are favoured by the majority of land-owners in the pariſh. At the era of 1749, the land-owners in ſome of the northern and middle counties of Scotland were more generally attached to the conſtitution of the church of England than to that of their own eſtabliſhment; and ſuch was certainly the caſe in the pariſh of Fordown.

But whatever was the cauſe of Mr Campbell's failure, he failed by a very ſmall number, and was not long without an eſtabliſhment. In 1750, he was preſented, by Sir Thomas Burnett, of Leys, to the living of Banchary Ternan, on the Dee, about twenty miles weſt from Aberdeen. From this he was tranſlated, or, as the Scotch eccleſiaſtical phraſe is, *tranſported* to Aberdeen in 1756, and nominated one of the city miniſters, in the room of Mr John Biſſet deceaſed, a puritan of the old ſchool, whoſe ſtrictneſs and peculiarities are yet remembered by many in that place.

In 1759, on the deceaſe of principal Pollock, he was choſen principal of the Mariſchal college, and ſucceeded to the divinity chair in 1771, on Dr Alexander Gerard being tranſlated to the profeſſorſhip of divinity in King's-college. Before his ſettling in Aberdeen, he married Miſs Grace Farquharſon, daughter of Mr Farquharſon of Whitehouſe, by whom he had no iſſue. This amiable woman died about a year before him. They were an eminent pattern of conjugal affection.

From this time he enjoyed a remarkable ſhare of good health and ſpirits. He had, all his life, a rooted averſion to medicine. He got the better of every ailment by a total and rigorous abſtinence from all kind of ſuſtenance whatever; and it was not till he was attacked by an alarming illneſs, about two years before his death, that he was perſuaded by his friends to call in medical aid. What nature could do, ſhe had all along performed well; but her day was over, and ſomething of art became neceſſary. Then, for the firſt time, he owned the utility of medical men, and declared his recantation of the very mean opinion he had formerly entained of them and their art. A few months before his death, he reſigned his offices of principal, profeſſor of divinity, and one of the city miniſters, and was in all ſucceeded by Dr W. L. Brown, late of Utrecht, a man of diſtinguiſhed abilities. Dr Campbell retained all his faculties entire to the laſt, and died on the 6th of April 1796, in the 77th year of his age. His character has been ſo juſtly drawn by his ſucceſſor, that we ſhall give it to our readers in his words, adding only a circumſtance or two, which we have reaſon to think will contribute to endear his memory to every liberal and enlightened mind.

"Dr Campbell, as a public teacher, was long admired for the clearneſs and copiouſneſs with which he illuſtrated the great doctrines and precepts of religion, and the ſtrength and energy with which he enforced them. Intimately perſuaded of the truth and infinite conſequence of what revelation teaches, he was ſtrongly deſirous of carrying the ſame conviction to the minds of his hearers, and delivered his diſcourſes with that zeal which flows from ſtrong impreſſions, and that power of perſuaſion which is the reſult of ſincerity of heart, combined with clearneſs of underſtanding. He was ſatisfied, that the more the pure dictates of the goſpel were ſtudied, the more they would approve themſelves to the mind, and bring forth, in the affections and conduct, all the peaceable fruits of righteouſneſs. The unadulterated dictates of Chriſtianity, he was, therefore, only ſtudious to recommend and inculcate, and knew perfectly to diſcriminate them from the inventions and traditions of men. His chief ſtudy ever was, to direct belief to the great objects of practice; and, without theſe, he viewed the moſt orthodox profeſſion as "a ſounding braſs, and a tinkling cymbal." But, beſides the character of a preacher of righteouſneſs, he had alſo that of a teacher of the ſcience of divinity to ſuſtain. How admirably he diſcharged this duty, and with what effect he conveyed the ſoundeſt and moſt profitable inſtruction to the minds of his ſcholars, let thoſe declare who are now in various congregations of this country, communicating to their fellow

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Chriſtians the fruits of their ſtudies under ſo able and judicious a teacher. Diſcarding all attachment to human ſyſtems, merely conſidered as ſuch, he tied his faith to the Word of God alone, poſſeſſed the happieſt talent in inveſtigating its meaning, and communicated to his hearers the reſult of his own inquiries, with a preciſion and perſpicuity which brought light out of obſcurity, and rendered clear and ſimple what appeared intricate and perplexed. He expoſed, without reſerve, the corruptions which ignorance, craft, and hypocriſy, had introduced into religion, and applied his talent for ridicule to the beſt of all purpoſes, to hold up to contempt the abſurdities with which the pureſt and ſublimeſt truths had been loaded.

"Placed at the head of a public ſeminary of learning, he felt all the importance of ſuch a ſituation, and uniformly directed his influence to public utility. His enlarged and enlightened mind, juſtly appreciated the extenſive conſequence of the education of youth. He anticipated all the effects reſulting to the great community of mankind, from numbers of young men iſſuing, in regular ſucceſſion, from the univerſity over which he preſided, and occupying the different departments of ſocial life.

"His benevolent heart delighted to repreſent to itſelf the ſtudents under his direction uſefully and honourably diſcharging the reſpective duties of their different profeſſions; and ſome of them, perhaps, filling the moſt diſtinguiſhed ſtations of civil ſociety. With theſe proſpects before him, he conſtantly directed his public conduct to their attainment. He never ſuffered his judgment to be warped by prejudice or partiality, or his heart to be ſeduced by paſſion or private intereſt. Thoſe mean and ignoble motives by which many are actuated in the diſcharge of important truſts, approached not his mind. A certain honourable pride, if pride it may be called, diffuſed an uniform dignity over the whole of his behaviour. He felt the man degraded by the perverſion of public character. His underſtanding alſo clearly ſhewed him even perſonal advantage attached to ſuch principles and practice, as he adopted from a ſenſe of obligation, and thoſe elevated conceptions of real worth which were ſo congenial to his ſoul. He ſaw, he experienced, eſteem, reſpect, and influence, following in the train of integrity and beneficence; but contempt, diſgrace, averſion, and complete inſignificance, cloſely linked to corruption and ſelfiſhneſs. Little minds are ſeduced and overpowered by ſelfiſh conſiderations, becauſe they have not the capacity to look beyond the preſent advantage, and to extend to the miſery that ſtands on the other ſide of it. The ſame circumſtance that betrays the perverſity of their hearts, alſo evinces the weakneſs of their judgments.

"His reputation as a writer, is as extenſive as the preſent intercourſe of letters; not confined to his own country, but ſpread through every civilized nation. In his literary purſuits, he aimed not, as is very often the caſe, with men of diſtinguiſhed literary abilities, merely at eſtabliſhing his own celebrity, or increaſing his fortune; but had chiefly at heart the defence of the great cauſe of Religion, or the elucidation of her dictates.

"At an early period he entered the liſts as a champion for Chriſtianity againſt one of its acuteſt opponents. He not only triumphantly refuted his arguments, but even conciliated his reſpect by the handſome and dexterous manner in which his defence was conducted. While he refuted the infidel, he ſpared the man, and exhibited the uncommon ſpectacle of a polemical writer poſſeſſing all the moderation of a Chriſtian. But while he defended Chriſtianity againſt its enemies, he was deſirous of contributing his endeavours to increaſe, among its profeſſors, the knowledge of the ſacred writings. Accordingly, in the latter part of his life, he favoured the world with a work, the fruit of copious erudition, of unwearied application, for almoſt thirty years, and of a clear and comprehenſive judgment. We have only to regret, that the other writings of the New Teſtament have not been elucidated by the ſame pen that tranſlated the Goſpels. Nor were his literary merits confined to theology, and the ſtudies more immediately connected with it. Philoſophy, and the fine arts, are alſo indebted to his genius and labours; and in him the polite ſcholar was eminently joined to the deep and liberal divine.

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"Political principles will always be much affected by general character. This was alſo the caſe with Dr Campbell. In politics, he maintained that moderation which is the ſureſt criterion of truth and rectitude, and was equally diſtant from thoſe extremes into which men are ſo apt to run on great political queſtions. He cheriſhed that patriotiſm which conſiſts in wiſhing, and endeavouring to promote, the greateſt happineſs of his country, and is always ſubordinate to univerſal benevolence. Firmly attached to the Britiſh conſtitution, he was animated with that genuine love of liberty which it inſpires and invigorates. He was equally averſe to deſpotiſm and to popular anarchy; the two evils into which political parties are ſo frequently hurried, to the deſtruction of all that is valuable in government. Party-ſpirit, of whatever deſcription, he conſidered as having an unhappy tendency to pervert, to the moſt pernicious purpoſes, the beſt principles of the human mind, and to clothe the moſt iniquitous actions with the moſt ſpecious appearances. Although tenacious of thoſe ſentiments, whether in religion or politics, which he was convinced to be rational and juſt, he never ſuffered mere difference of opinion to impair his good will, to obſtruct his good offices, or to cloud the cheerfulneſs of converſation. His own converſation was enlivened by a vein of the moſt agreeable pleaſantry."

So far was he from being influenced by jealouſy, or any portion of that corporation ſpirit which ſometimes incites men of undoubted abilities to detract from the merit of every writer who fills not a ſtation as conſpicuous as their own, that he was loud in his praiſes of thoſe, whom men of meaner minds would have looked upon with diſguſt, as upon preſumptuous rivals. This generoſity was fully experienced by the writer of the article Miracle, in the Encyclopædia, who, though he had preſumed to treat the ſubject differently from Dr Campbell, received from him ſuch a teſtimony of approbation of what he had done, as he will hardly look for from any other man in ſimilar circumſtances.

Among his other qualities, which ſo much endeared him to all who had the honour of his acquaintance, Dr Campbell poſſeſſed an uncommon facility of paſſing from the graveſt to the moſt airy ſubjects, and from the livelieſt to the graveſt, without degrading the one or diminiſhing the pleaſure of the other. The infirmities of age abated not the cheerfulneſs of his temper, nor did even the perſuaſion of approaching diſſolution impair his ſerenity.

We cannot conclude this ſhort ſketch better than with a liſt of his works, in the order in which they were publiſhed. In 1752, he publiſhed a Sermon, preached before the Synod of Aberdeen.

1761. A Diſſertation on Miracles, againſt Mr Hume. This treatiſe is well known to the learned world. He obtained, and deſervedly obtained, a very high reputation, not only from the able manner in which he handled the ſubject, but from the liberal ſtyle in which he addreſſed his antagoniſt. It was ſpeedily tranſlated into French, German, and Dutch.

1771. A Sermon before the Society for Propagating Chriſtian Knowledge, Edinburgh.

———— before the Synod of Aberdeen.

1776. The Philoſophy of Rhetoric, 2 vols 8vo. A work which diſcovers a clearneſs of diſcernment, and accuracy of obſervation, which juſtly intitled him to be ranked among the moſt judicious critics. He entered on this inquiry as early as 1750, when a part of the work was compoſed. The laws of elegant compoſition and criticiſm are laid down with great perſpicuity: but the moſt valuable part of the work is undoubtedly the *theory of evidence*, to which we know nothing ſuperior, perhaps nothing equal, on the ſubject, in our own or any other language. His philoſophy, in general, is the philoſophy of Dr Reid; and where he differs from that acute reaſoner reſpecting *abſtraction*, and ſome other objects of metaphyſical diſquiſition, we think it impoſſible to refuſe him the pre-eminence in every thing but ſtyle.

1777. A Sermon on the King's Faſt-day, on Allegiance, firſt printed in 4to, and afterwards, at the expence of government, ſix thouſand copies were printed in 12mo, enlarged with notes, and ſent to America, when the unhappy ſtruggle had, however, put on appearances which prevented the effect hoped for from this ſermon.

1780. An Addreſs to the People of Scotland on the Alarms which have been raiſed by what is called the Popiſh Bill. This is a powerful diſſuaſive from bigotry, and every ſpecies of religious perſecution.

1793. His *Magnum Opus*. The tranſlation of the Goſpels, with Preliminary Diſſertations, 2 vols 4to.

CAMPBELL *Co.* in Virginia, lies E. of Bedford co. on Staunton River. It is 45 miles long, and 30 broad, and contains 7,685 inhabitants, including 2,488 ſlaves.—*Morſe.*

CAMPBELLTOWN, a village in Dauphin co. Pennſylvania, which ſtands near a water of Quitipihilla Creek; 13 miles E. of Harriſburgh, and 96 N. W. of Philadelphia.—*ib.*

CAMPBELLTOWN, in N. Carolina, is a large and flouriſhing town on a branch of Cape Fear River 100 miles above Wilmington; having, according to Bartram, "above 100 houſes, many wealthy merchants, reſpectable public buildings, a vaſt reſort of inhabitants and travellers, and continual briſk commerce by waggons, from the back ſettlements, with large trading boats."—*ib.*

CAMPBELL's *Fort*, in the ſtate of Tenneſſee, ſtands near the junction of Holſton River with the Tenneſſee; diſtant 135 miles from Abingdon, in Waſhington co. Virginia, and 445 W. of Richmond in Virginia.—*ib.*

CAMPBELL's *Salines*, in North Holſton, in the ſtate of Tenneſſee, are the only ones that have yet been diſcovered on the upper branches of the Tenneſſee, though great ſearch has been made for them. Large bones, like thoſe found at Big Bone Lick, have been dug up here; and other circumſtances render the tract which contains the ſalines a great natural curioſity. Capt. Charles Campbell, one of the firſt explorers of the weſtern country, made the diſcovery of this tract in 1745. In 1753, he obtained a patent for it from the governor of Virginia. His ſon the late Gen. William Campbell, the ſame who behaved ſo gallantly in the years 1780, and 1781, became owner of it on his death. But it was not till the time of his death, when ſalt was very ſcarce and dear, that ſalt-water was diſcovered, and ſalt made by a poor man. Since that time it has been improved to a conſiderable extent, and many thouſands of people are now ſupplied from it, with ſalt of a ſuperior quality, and at a low price. The tract conſiſts of about 300 acres of ſalt marſh land, of as rich a ſoil as can be imagined. In this flat, pits are ſunk, in order to obtain the ſalt water. The beſt is found from 30 to 40 feet deep; after paſſing through the rich ſoil or mud, from 6 to 10 feet, you come to a very brittle lime-ſtone rock, with cracks or chaſms, through which the ſalt water iſſues into the pits, whence it is drawn by buckets and put into the boilers, which are placed in furnaces adjoining the pits. The hills that ſurround this flat are covered with fine timber; and a coal mine has been diſcovered not far from it. —*ib.*

CAMPEACHY, a town in the audience of Old-Mexico, or New-Spain, and province of Yucatan, ſituated on the bay of Campeachy, near the W. ſhore. Its houſes are well built of ſtone; when taken by the Spaniards it was a large town of 3000 houſes, and had conſiderable monuments of Indian art and induſtry. There is a good dock and fort, with a governor and garriſon, which commands both the town and harbor. It has been often ſtormed and taken, both by the Engliſh and French buccaniers, in 1659, 1678, and laſt in 1685, when theſe freebooters united, and plundered every place within 15 leagues round it, for the ſpace of two months; they afterwards ſet fire to the fort and town, which the governor, who kept the field with his men, would not ranſom; and to complete the pillage by a ſingular piece of folly, the French buccaniers celebrated the feaſt of their king, the day of St Louis, by burning to the value of £.50,000 ſterling of Campeachy wood, which was a part of their ſhare of the plunder. The port is large but ſhallow. It was a ſtated market for logwood, of which great quantities grew in the neighbourhood, before the Engliſh landed there, and cut it at the iſthmus, which they entered at Trieſta Iſland, near the bottom of the bay, 40 leagues S. W. from Campeachy. The chief manufacture here is cotton cloth. Lat. 15. 40. long. 91. 30.—*ib.*

CAMPHOR, or CAMPHIRE (ſee *Encycl.*), is, in China, obtained by boiling the branches, twigs, and leaves, of the *Laurus-Camphora* in water, upon the ſurface of which it is found ſwimming in the form of an oil, or adhering, in a glutinous form, to a wooden rod, with which the boiling matter is conſtantly ſtirred. The glutinous maſs is then mixed with clay and lime, and put into an earthen veſſel, with another of the ſame ſize properly luted over it; the lower veſſel being placed over a ſlow fire, the camphor gradually ſublimes through the clay and lime, and adheres to the ſides of the upper veſſel, forming a cake of a ſhape correſponding to the cavity which received it. It is, however, leſs pure and much weaker than what is diſcovered in a ſolid ſtate among the fibres of the trunk, as turpentine is found in different ſorts of pines. In the great, but ill-peopled, iſland of Borneo, and alſo in Japan, the camphor tree is felled for the ſole purpoſe of finding this coſtly drug in ſubſtance among the ſplinters of the trunk, in the ſame manner as other trees are felled in Louiſiana merely for collecting the fruit they bear upon their ſummits. The Borneo, or Japan camphor, is pure, and ſo very ſtrong, as readily to communicate much of its odour and its virtues to other inſpiſſated oils, which thus paſs for real camphor; and this adulterated drug is ſold by Chineſe artiſts at a vaſtly lower price than they gave themſelves for the genuine ſubſtance from Borneo or Japan.

Sir George Staunton, from whom we have this account, does not inform us whether the camphor-tree of China, if felled and torn into ſplinters, would not produce as large quantities of the drug, and equally pure, as the trees of Borneo and Japan; but he aſſures us, that in China it is never ſo torn, being there a large and valuable timber-tree. "It is uſed (ſays he) in the beſt buildings of every kind, as well as for maſts of veſſels, and bears too high a price to allow of any part, except the branches, being cut up for the ſake of the drug."

CAMPO BELLO, a long and narrow iſland, on the E. coaſt of Waſhington co. diſtrict of Maine, and the N. eaſternmoſt of all the iſlands of the diſtrict. It lies at the mouth of a large bay into which Cobſcook river empties, and has communication with Paſſamaquoddy bay on the N. by two channels; the one between the W. ſide of Deer Iſland and the continent; the other into the mouth of Paſſamaquoddy Bay between Deer Iſland and the N. end of Campo Bello Iſland which lies in about N. lat. 44. 48. The S. end is 5 miles N. weſterly from Grand Mannan Iſland.—*Morſe.*

CANABAC, an iſland lying contiguous to BULAM on the weſtern coaſt of Africa, and inhabited by a fierce people, governed by two kings or chiefs. It would appear that the Canabacs had been very troubleſome to their neighbours, ſince the inhabitants of ſome other iſlands in that cluſter rejoiced at the ſettlement of the Engliſh in Bulam, hoping to find in them a defence againſt the uſurpations of the Canabacs.

CANADA *Creeks.* There are three creeks which bear this name; one a water of Wood creek, which it meets 4 or 5 miles N. N. W. of Fort Stanwix or New Fort Schuyler. The other two are northern branches of Mohawk River; the *upper* one mingles its waters with the Mohawk in the townſhip of Herkemer, on the German flats, 16 miles below Old Fort Schuyler; over the mouth of it is a ſightly and ingeniouſly conſtructed bridge. The other empties into the Mohawk 13 miles below. Both theſe are long, rapid and unnavigable ſtreams, and bring a conſiderable acceſſion of water to the Mohawk. The lands on theſe creeks are exceedingly rich and valuable, and faſt ſettling.—*Morſe.*

CANADA SAGA, or *Seneca Lake*, a handſome piece of water from 35 to 40 miles long, and about 2 miles broad, in New-York. At the N. W. corner of the Lake ſtands the town of Geneva, and on the E. ſide between it and Cayuga, are the towns of Romulus, Ovid, Hector and Ulyſſes, in Onondago co. New-York. Its outlet is Scayace River which alſo receives the waters of Cayuga Lake 9 miles N. E. from the mouth of Canada Saga, 18 miles below Geneva, on the ſame ſide of the lake ſtands the Friend's ſettlement, founded by Jemima Wilkinſon; there are 80 families in it, each has a fine farm, and are quiet, induſtrious people.—*ib.*

CANAJOHARY, a poſt town in Montgomery co. New-York, ſituated on the S. ſide of Mohawk River comprehending a very large diſtrict of fine country, 40 miles W. of Schenectady, and 56 miles from Albany. In the ſtate cenſus of 1796, 730 of the inhabitants appear to be electors. A creek named Canajohary enters the Mohawk in this town. In this townſhip, on the bank of the Mohawk, about 50 miles from Schenectady, is *Indian Caſtle*, ſo called, the ſeat of old king Hendrick, who was killed in Sept. 1755, at Lake George, fighting for the Britiſh and Americans againſt the French. Here are now the remains of a Britiſh fort, built during that war, about 60 paces ſquare. A gold coin of the value of about 7 dollars was found in theſe ruins in 1793. About a mile and half W. of this fort ſtands a church, which is called Brant's church, which the noted chief of that name is ſaid to have left with great reluctance. This was the principal ſeat of the Mohawk nation of Indians, and abounds with apple trees of their planting, from which is made cider of an excellent quality.—*ib.*

CANALS OF COMMUNICATION may be of ſuch advantage in a commercial or agricultural country, that every attempt to render them more convenient, and leſs expenſive in the conſtruction, is intitled to public notice. In the Encyclopædia, an account, ſufficiently perſpicuous, is given of the common canals with locks; but in many caſes it is very difficult to provide a ſufficient quantity of water for the conſumption of a canal where many boats are to paſs. Different attempts have therefore been made, by ingenious men, to ſave water in the paſſing of boats or lighters from one lock of a canal to another; and, among theſe, perhaps none is more deſerving of public favour than the following, by the late Mr James Playfair of Ruſſel-ſtreet, architect. We ſhall ſtate his invention in his own words.

"The nature and principle of this manner of ſaving water conſiſt in letting the water which has ſerved to raiſe or fall a boat or barge from the lock, paſs into reſervoirs or ciſterns, whoſe apertures of communication with the lock are upon different levels, and which may be placed or conſtructed at the ſide or ſides of the lock with which they communicate, or in any other contiguous ſituation that circumſtances may render eligible; which apertures may be opened or ſhut at pleaſure, ſo that the water may paſs from the lock to each reſervoir of the canal, or from each reſervoir to the lock, in the following manner: The water which fills the lock, when a boat is to aſcend or deſcend, inſtead of being paſſed immediately into the lower part of the canal, is let paſs into theſe ciſterns or reſervoirs, upon different levels; then, their communications with the lock being ſhut, they remain full until another veſſel is wanted to paſs; then, again, the ciſterns are emptied into the lock, which is thereby nearly filled, ſo that only the remainder which is not filled is ſupplied from the higher part of the canal. Each of theſe ciſterns muſt have a ſurface not leſs than that of the lock, and muſt contain half as much water as is meant to be expended for the paſſing of each veſſel. The ciſtern the moſt elevated is placed twice its own depth (meaſuring by the aperture, or communicating opening of the ciſterns) under the level of the water in the higher part of the canal. The ſecond ciſtern is placed once its own depth under the firſt, and ſo on are the others, to the loweſt; which laſt is placed once its own depth above the level of the water in the lower part of the canal. The apertures of the intermediate ciſterns, whatever their number may be, muſt all be equally divided into different levels; the ſurface of the water in the one being always on the level of the bottom of the aperture of the ciſtern which is immediately above. As an example of the manner and rule for conſtructing theſe ciſterns, ſuppoſe that a lock is to be conſtructed twelve feet deep, that is, that the veſſel may aſcend or deſcend twelve feet in paſſing. Suppoſe the lock ſixty feet long and ſix feet wide, the quantity of water required to fill the lock, and to paſs a boat, is 4320 cubic feet; and ſuppoſe that, in calculating the quantity of water that can be procured for ſupplying the canal, after allowing for waſte, it is found (according to the number of boats that may be expected to paſs) that there will not be above 800 cubic feet for each; then it will be neceſſary to ſave five-ſixths of the whole quantity that in the common caſe would be neceſſary: to do which ten ciſterns muſt be made (the mode of placing which is expreſſed in the drawing, fig. 1. Plate VII.), each of which muſt be one foot deep, or deeper at pleaſure, and each muſt have a ſurface of 360 feet ſquare, equal to the ſurface of the lock. The bottom of the aperture of the loweſt ciſtern muſt be placed one foot above the level of the water in the lower part of the canal, or eleven feet under the level of the high water; the ſecond ciſtern muſt be two feet above the level of the low water; the third three feet, and ſo on of the others; the bottom of the tenth, or uppermoſt ciſtern, being ten feet above the low water, and two feet lower than the high water; and, as each ciſtern muſt be twelve inches in depth, the ſurface of the water in the higher ciſtern will be one foot under the level of the water in the upper part of the canal. The ciſterns being thus conſtructed, when the lock is full, and the boat to be let down, the communications between the lock and the ciſterns, which until then have all been ſhut, are to be opened in the following manner: firſt, the communication with the higher ciſtern is opened, which, being at bottom two feet under the level of the water in the lock, is filled to the depth of one foot, the water in the lock deſcending one foot alſo at the ſame time; that communication is then ſhut, and the communication between the lock and the ſecond ciſtern is opened; one foot more of the water then paſſes into that ciſtern from the lock, and fills it; the opening is then ſhut: the ſame is done with the third, fourth, fifth, ſixth, ſeventh, eighth, ninth, and tenth, ciſterns, one by one, until they are all filled; and, when the tenth, or lowermoſt ciſtern, is filled, there remains but two feet depth of water in the lock. The communication between the lock and the lower part of the canal is then opened, and the laſt two feet depth of water is emptied into the lower part of the canal. By this means, it is evident, that, inſtead of twelve feet depth of water being let deſcend into the lower part of the canal, there is only two feet depth that deſcends, or one-ſixth of the whole; therefore, inſtead of 4320 cubic feet being uſed, there are only 720 cubic feet uſed: the remainder of the water in the ciſterns being uſed as follows. When another boat is to mount, the ſluices being then ſhut, and the boat in the lock, the tenth or lowermoſt ciſtern is emptied into the lock, which it fills one foot; the communication being then ſhut, the next loweſt ciſtern, or the ninth, is emptied into the lock, which is thereby filled another foot; and ſo, in like manner, all the other ciſterns are emptied one after another, until the higher ciſtern being emptied, which fills the tenth foot of water in the lock, there remains but two feet of water to fill, which is done from the upper part of the canal, by opening the higher ſluice to paſs the boat; by that means, the ſame quantity of water deſcends from the upper part of the canal into the lock, that in the other caſe deſcended from the lock into the lower part of the canal; ſo that, in both caſes, the ſame quantity of water is ſaved, that is, five-ſixths of what would be neceſſary were there no ciſterns. Suppoſe again that, upon the ſame canal, and immediately after the twelve feet lock, it would be advantageous to conſtruct one of eighteen feet; then, in order not to uſe any greater quantity of water, it will be neceſſary to have ſixteen ciſterns, upon different levels, communicating with the lock in the ſame manner. Should, again, a lock of only ſix feet be wanted, after that of eighteen, then it will only be neceſſary to have four ciſterns on different levels, and ſo of any other height of lock. The rule is this: for finding the number and ſize of the ciſterns, each ciſtern being the ſame in ſuperficies with the lock, its depth muſt be ſuch as to contain one half the quantity of water meant to be uſed in the paſſing of one boat. The depth of the lock, divided by the depth neceſſary for ſuch a ciſtern, will give, in all caſes, the whole number of ciſterns, and two more: deduct the number two, therefore, from the number which you find by dividing the depth of the lock by the depth of one ciſtern, and you have always the number of ciſterns required; which are to be placed upon different levels, according to the rule already given. The above is the principle and manner of uſing the lock, for ſaving water in canals, and for enabling engineers to conſtruct locks of different depths upon the ſame canal, without uſing more water for the deep locks than for the ſhallow ones. With regard to the manner of diſpoſing the ciſterns, the circumſtances of the ground, the declivity, &c. will be the beſt guide for the engineer."

But ſuppoſing a ſufficiency of water, or admitting that this method of Mr Playfair's of ſaving it, where defective, is adequate to his fondeſt expectations, ſtill, in paſſing numerous locks, where the riſe is conſiderable, the interruption is ſo great, that it has often been wiſhed that an eligible method of lowering and elevating boats could be deviſed, without the aſſiſtance of water-locks. Though this is evidently at firſt view practicable, and ſeveral different modes of doing it have been ſuggeſted, ſome of which have actually been carried into effect, yet all of them have been found to be attended with ſuch inconvenience as to render an improvement in this reſpect ſtill neceſſary.

In China, where water-carriage is more generally practiſed than in any kingdom of Europe, boats are raiſed and lowered from one canal into another by ſliding them along an inclined plane: but the contrivances for effecting that purpoſe are ſo awkward, and ſuch a number of hands are required, that it has in general been deemed inexpedient to reſort to that mode of practice in Europe. Several devices that diſcover conſiderable ingenuity, however, have been publiſhed, with a view to facilitate this operation; either by rendering the motion up the inclined plane more equable, or producing a power ſufficient to move theſe great weights. But none of them have yet been ſo ſimple in their conſtruction as could be wiſhed, nor have they afforded ſatisfaction in practice. For the greater part of them, likewiſe, patents have been granted; ſo that whatever be their value, no engineer could avail himſelf of them without previouſly purchaſing a licence from the patentee.

The following contrivance for this purpoſe is the invention of James Anderſon, LL. D. whoſe knowledge of economics is well known, and of whoſe public ſpirit there cannot be a doubt. Inſtead of applying for a patent, to ſecure to himſelf the fruits of his ingenuity, he publiſhed, for the good of his countrymen in general, his device, in the View of the Agriculture of the County of Aberdeen, which he drew up for the conſideration of the board of agriculture. He introduces it to public notice with juſtly obſerving, that it poſſeſſes at leaſt the merit of ſimplicity, in as high a degree, perhaps, as could be wiſhed; and, "in the opinion (ſays he) of very good judges of matters of this ſort, to whom the plan has been ſhewn, it has been deemed fully adequate to the purpoſe of raiſing and lowering boats of a moderate ſize, that is of 20 tons, or downwards; and it is the opinion of moſt men with whom I have converſed, who are beſt acquainted with the inland navigations, that a boat of from 10 to 15 tons is better than thoſe of a larger ſize. When ſeveral are wanted to be ſent at once, they may be affixed to one another, as many as the towing-horſe can conveniently draw. Were boats of this ſize adopted, and were all the boats on one canal to be of the ſame dimenſions, it would prove a great convenience to a country in a ſtate of beginning improvements; becauſe the expence of ſuch a boat would be ſo trifling, that every farmer could have one for himſelf, and might of courſe make uſe of it when he pleaſed, by the aid of his own horſe, without being obliged to have any dependence on the time that might ſuit the convenience of his neighbour; and if two or more boats were going from the ſame neighbourhood, one horſe could ſerve the whole.

"You are to ſuppoſe that fig. 2. (Plate VII.) repreſents a bird's-eye view of this ſimple apparatus, as ſeen from above. A is ſuppoſed to be the upper reach of the canal, and B the lower reach, with the apparatus between the two. This conſiſts of three diviſions; the middle one, extending from C to D, is a ſolid piece of maſonry, raiſed from a firm foundation below the level of the bottom of the ſecond reach; this is again divided into five parts, viz. *d d d*, where the wall riſes only to the height of the water in the upper reach, and *e e*, two pillars, raiſed high enough to ſupport the pivots of a wheel or pulley *g*, placed in the poſition there marked.

"The ſecond diviſion *h* conſiſts of a wooden coffer, of the ſame depth nearly as the water in the upper reach, and of a ſize exactly fitted to contain one of the boats. This communicates directly with the upper reach, and being upon the ſame plane with it, and ſo connected with it as to be water-tight, it is evident from inſpection, that nothing can be more eaſy than to float a boat into this coffer from the upper reach; the part of the wheel that projects over it being at a ſufficient height above it, ſo as to occaſion no ſort of interruption.

"Third diviſion. At *i* is repreſented another coffer, preciſely of the ſame dimenſions with the firſt. But here two ſluices, which were open in the former, and only repreſented by dotted lines, are ſuppoſed to be ſhut, ſo as to cut off all communication between the water in the canal and that in the coffer. As it was impoſſible to repreſent this part of the apparatus on ſo ſmall a ſcale, for the ſake of illuſtration it is repreſented more at large in fig. 5. where A, as before, repreſents the upper reach of the canal, and *h* one of the coffers. The ſluice *k* goes into two cheeks of wood, joined to the maſonry of the dam of the canal, ſo as to fit perfectly cloſe; and the ſluice *f* fits, equally cloſe, into cheeks made in the ſide of the coffer for that purpoſe; between theſe two ſluices is a ſmall ſpace *o*. The coffer, and this diviſion *o*, are to be ſuppoſed full of water, and it will be eaſy to ſee that theſe ſluices may be let down, or drawn up at pleaſure, with much facility.

"Fig. 6. repreſents a perpendicular ſection of theſe parts in the ſame direction as in fig. 5. and in which the ſame letters repreſent the ſame parts.

"Things being thus arranged, you are to ſuppoſe the coffer *h* to be ſuſpended, by means of a chain paſſed over the pulley, and balanced by a weight that is ſufficient to counterpoiſe it, ſuſpended at the oppoſite end of the chain. Suppoſe, then, that the counterpoiſe be made ſomewhat lighter than the coffer with its contents, and that the line *m n* (fig. 6.) repreſents a diviſion between the ſolid ſides of the dam of ſeparation, which terminates the upper reach, and the wooden coffer, which had been cloſed only by the preſſure of its own weight (being puſhed a very little from A towards B, beyond its preciſe perpendicular ſwing), and that the joining all round is covered with liſts of cloth put upon it for that purpoſe; it is evident that, ſo long as the coffer is ſuſpended to this height, the joining muſt be water-tight; but no ſooner is it lowered down a little than this joining opens, the water in the ſmall diviſion *o* is allowed to run out, and an entire ſeparation is made between the fixed dam and this moveable coffer, which may be lowered down at pleaſure without loſing any part of the water it contained.

"Suppoſe the coffer now perfectly detached, turn to fig. 3. which repreſents a perpendicular ſection of this apparatus, in the direction of the dotted line *p p* (fig. 2.). In fig. 3. *h* repreſents an end view of the coffer, indicated by the ſame letter as in fig. 2. ſuſpended by its chain, and now perfectly detached from all other objects, and balanced by a counterpoiſe *i*, which is another coffer exactly of the ſame ſize, as low down as the level of the lower reach. From inſpection only it is evident, that, in proportion as the one of theſe weights riſes, the other muſt deſcend. For the preſent, then, ſuppoſe that the coffer *h* is by ſome means rendered more weighty than *i*, it is plain it will deſcend while the other riſes; and they will thus continue till *h* comes down to the level of the lower reach, and *i* riſes to the level of the higher one.

“ Fig. 4. repreſents a ſection in the direction A B (fig. 2.), in which the coffer *i* (ſeen in both ſituations) is ſuppoſed to have been gradually raiſed from the level of the lower reach B, to that of the higher A, where it now remains ſtationary; while the coffer *h* (which is concealed behind the maſonry) has deſcended in the mean time to the level of the lower reach, where it cloſes by means of the juncture *r s*, fig. 6. (which juncture is covered with liſts of cloth, as before explained at *m n*, and is of courſe become water-tight,) when, by lifting the ſluice *t*, and the correſponding ſluice at the end of the canal, a perfect communication by water is eſtabliſhed between them. If, then, inſtead of water only, this coffer had contained a boat, floated into it from the upper reach, and then lowered down, it is very plain, that when theſe ſluices were removed, after it had reached the level of the lower reach, that boat might have been floated out of the coffer with as much facility as it was let into it above. Here then we have a boat taken from the higher into the lower canal; and, by reverſing this movement, it is very obvious that it might be, with equal eaſe, raiſed from the lower into the higher one. It now only remains that I ſhould explain by what means the equilibrium between theſe counter-balancing weights can be deſtroyed at pleaſure, and the motion of courſe produced.

“ It is very evident, that if the two correſponding coffers be preciſely of the ſame dimenſions, their weight will be exactly the ſame when they are both filled to the ſame depth of water. It is equally plain, that ſhould a boat be floated into either or both of them, whatever its dimenſions or weight may be, ſo that it can be contained afloat in the coffer, the weight of the coffer and its contents will continue preciſely the ſame as when it was filled with water only: hence, then, ſuppoſing one boat is to be lowered, or one to be raiſed at a time, or ſuppoſing one to be raiſed and another lowered at the ſame time—they remain perfectly in equilibrium in either place, till it is your pleaſure to deſtroy that equilibrium. Suppoſe then, for the preſent, that both coffers are loaded with a boat in each, the double ſluices both above and below cloſed; and ſuppoſe alſo that a ſtop-cock *u*, in the under edge of the ſide of the lower coffer (fig. 4. and 6.), is opened, ſome of the water which ſerved to float the boat in the coffer will flow out of it, and conſequently that coffer will become lighter than the higher one; the upper coffer will of courſe deſcend, while the other mounts upwards. When a gentle motion has been thus communicated, it may be prevented from accelerating, merely by turning the ſtop cock ſo as to prevent the loſs of more water, and thus one coffer will continue to aſcend, and the other to deſcend, till they have aſſumed their ſtations reſpectively; when, in conſequence of a ſtop below, and another above, they are rendered ſtationary at the level of the reſpective canals (A).

“ Preciſely the ſame effect will be produced when the coffers are filled entirely with water.

“ It is unneceſſary to add more to this explanation, except to obſerve, that the ſpace for the coffer to deſcend into muſt be deeper than the bottom of the lower canal, in order to allow a free deſcent for the coffer to the requiſite depth; and of courſe it will be neceſſary to have a ſmall conduit to allow the water to get out of it. Two or three inches free, below the bottom of the canal, is all that would be neceſſary.

“ Where the height is inconſiderable, there will be no occaſion for providing any counterpoiſe for the chain, as that will give only a ſmall addition to the weight of the undermoſt coffer, ſo as to make it preponderate, in circumſtances where the two coffers would otherwiſe be in perfect equilibrium: but, where the height is conſiderable, there will be a neceſſity for providing ſuch a counterpoiſe; as, without it, the chain by becoming more weighty every foot it deſcended, would tend to deſtroy the equilibrium too much, and accelerate the motion to an inconvenient degree. To guard againſt this inconvenience, let a chain of the ſame weight, per foot, be appended at the bottom of each coffer, of ſuch a length as to reach within a few yards of the ground where the coffer is at its greateſt height (ſee fig. 3.); it will act with its whole weight upon the higheſt coffer while in this poſition; but, as that gradually deſcended, the chain would reach the ground, and, being there ſupported, its weight would be diminiſhed in proportion to its deſcent; while the weight of the chain on the oppoſite ſide would be augmented in the ſame proportion, ſo as to counterpoiſe each other exactly, in every ſituation, until the uppermoſt chain was raiſed from the ground. After which it would increaſe its weight no more; and, of courſe, would then give the under coffer that preponderance which is neceſſary for preſerving the machine ſteady. The under coffer, when it reached its loweſt poſition, would touch the bottom on its edges, which would then ſupport it, and keep every thing in the ſame poſition, till it was made lighter for the purpoſe of aſcending.

“ What conſtitutes one particular excellence of the apparatus here propoſed, is, that it is not only unlimited as to the extent of the riſe or depreſſion of which it is ſuſceptible (for it would not require the expenditure of one drop more water to lower it one hundred feet than one foot); but it would alſo be eaſy ſo to augment the number of pulleys at any one place as to admit of two, three, four, or any greater number of boats being lowered or elevated at the ſame time; ſo that let the ſucceſſion of boats on ſuch a canal be nearly as rapid as that of carriages upon a highway, none of them need be delayed one moment to wait an opportunity of paſſing; a thing that is totally impracticable where water-locks are employed; for the intercourſe, on every canal conſtructed with water-locks, is neceſſarily limited to a certain degree, beyond which it is impoſſible to force it.

“ For example; ſuppoſe a hundred boats are following each other, in ſuch a rapid ſucceſſion as to be only half

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(A) “ It does not ſeem neceſſary to adopt any other contrivance than the above for regulating the motions; but if it ſhould be found neceſſary, it would be eaſy to put a ratch-wheel on the ſame axle.

half a minute behind each other: By the apparatus here propoſed, they would all be elevated preciſely as they came; in the other, let it be ſuppoſed that the lock is ſo well conſtructed as that it takes no more than five minutes to cloſe and open it; that is, ten minutes in the whole to each boat (for the lock, being once filled, muſt be again emptied before it can receive another in the ſame direction): at this rate, ſix boats only could be paſſed in an hour, and of courſe it would take ſixteen hours and forty minutes to paſs the whole hundred; and as the laſt boat would reach the lock in the ſpace of fifty minutes after the firſt, it would be detained fifteen hours and fifty minutes before its turn would come to be raiſed. This is an immenſe detention; but if a ſucceſſion of boats, at the ſame rate, were to follow continually, they never could paſs at all. In ſhort, in a canal conſtructed with water-locks, not more than ſix boats, on an average, can be paſſed in an hour, ſo that beyond that extent all commerce muſt be ſtopped; but, of the plan here propoſed, ſixty, or ſix hundred, might be paſſed in an hour if neceſſary, ſo as to occaſion no ſort of interruption whatever. Theſe are advantages of a very important nature, and ought not to be overlooked in a commercial country.

“ This apparatus might be employed for innumerable other uſes as a moving power, which it would be foreign to our preſent purpoſe here to ſpecify. Nor does its power admit of any limitation, but that of the ſtrength of the chain, and of the coffers which are to ſupport the weights. All the other parts admit of being made ſo immoveably firm as to be capable of ſupporting almoſt any aſſignable weight.

“ I will not enlarge on the benefits that may be derived from this very ſimple apparatus: its cheapneſs, when compared with any other mode of raiſing and lowering veſſels that has ever yet been practiſed, is very obvious; the waſte of water it would occaſion is next to nothing; and when it is conſidered that a boat might be raiſed or lowered fifty feet nearly with the ſame eaſe as five, it is evident that the interruptions which ariſe from frequent locks would be avoided, and an immenſe ſaving be made in the original expence of the canal, and in the annual repairs.

“ It is alſo evident, that an apparatus, on the ſame principle might be eaſily applied for raiſing coals or metals from a great depth in mines, wherever a very ſmall ſtream of water could be commanded, and where the mine was level-free.”

CANANDAQUA, a poſt town, lake, and creek, in Ontario co. New-York. It is the ſhire town of the co. ſituated on the N. end of the lake of the ſame name, at its outlet into Canandaqua creek. The lake is about 20 miles long and 3 broad, and ſends its waters in a N. eaſtward and eaſtward courſe 35 miles to Seneca River. This is the ſcite of an ancient Indian town of the ſame name, and ſtands on the road from Albany to Niagara, 22 miles E. from Hartford in Geneſſee River; 16 miles W. of Geneva, and 235 miles N. W. from New-York city, meaſuring in a ſtraight line, and 340 by Albany road. This ſettlement was begun by Meſſrs. Gorham and Phelps, and is now in a flouriſhing ſtate. There are about 30 or 40 houſes, ſituated on a pleaſant ſlope from the lake; and the adjoining farms are under good cultivation. By the ſtate cenſus of 1796, it appears there are 291 electors in this townſhip.—*Morſe.*

CANARY-BIRD, of which a deſcription is given in the Encyclopædia, was not known in Europe till towards the end of the 15th century. Even in 1555, Bellon, who about that time deſcribed all the birds then known, does not ſo much as mention it. When it was firſt brought from the Canary Iſlands, it was ſo dear that it could be purchaſed only by people of fortune, who were often impoſed upon. It was called the *ſugar-bird*, becauſe it was ſaid to be fond of the ſugar-cane, and could eat ſugar in great abundance. This is rather a ſingular circumſtance, ſugar being to many fowls a poiſon. Experiments have ſhewn, that a pigeon, to which four drams of ſugar was given, died in four hours; and that a duck, which had ſwallowed five drams, did not live ſeven hours.

In the middle of the laſt century canary-birds began to be bred in Europe; and to this the following circumſtance, related by Olina, ſeems to have given occaſion: “ A veſſel which, among other commodities, was carrying a number of canary birds to Leghorn, was wrecked on the coaſt of Italy; and theſe birds being thus ſet at liberty, flew to the neareſt land, which was the iſland of Elba, where they found the climate ſo favourable, that they multiplied, and perhaps would have become domeſticated, had they not been caught in ſnares; for it appears that the breed of them there has been long deſtroyed. Olina ſays, that the breed ſoon degenerated; but it is probable, that by much the greater part of theſe canary-birds were males, which coupling with birds of the iſland, produced mules, ſuch as are deſcribed by Geſner and other naturaliſts.”

“ Various treatiſes have been publiſhed in different languages on the manner of breeding theſe birds, and many people have made it a trade, by which they have acquired conſiderable gain. It does no diſcredit to the induſtry of the Tyrolians, that they have carried it to the greateſt extent. At Ymſt there is a company, who, after the breeding ſeaſon is over, ſend out perſons to different parts of Germany and Switzerland to purchaſe birds from thoſe who breed them. Each perſon brings with him commonly from three to four hundred, which are afterwards carried for ſale, not only through every part of Germany, but alſo to England, Ruſſia, and even Conſtantinople. About ſixteen hundred are brought every year to England; where the dealers in them, notwithſtanding the conſiderable expence they are at, and after carrying them about on their backs, perhaps a hundred miles, ſell them for five ſhillings a piece. This trade, hitherto neglected, is now carried on in Schwarzwalde; and at preſent there is a citizen at Gottingen who takes with him every year to England ſeveral canary-birds and bulfinches (*loxia pyrrhula*), with the produce of which he purchaſes ſuch ſmall wares as he has occaſion for.”—*Profeſſor Beckmann's Hiſtory of Inventions and Diſcoveries.*

Canary-Seed. See Phalaris, *Encycl.*—Profeſſor Beckmann doubts whether the plant which bears the canary-ſeed be the *phalaris* of the ancients, becauſe that name ſeems to have been given by Pliny to more than one ſpecies of graſs. He thinks it very probable, however, that the plant which the modern botaniſts call *phalaris* was firſt brought from the Canary Iſlands to

Spain, where it began to be cultivated, as well as in the ſouth of France, as ſoon as canary-birds came into general eſteem. At preſent it is cultivated in various places, and forms no inconſiderable branch of trade, particularly in the iſland of Sicily, where it is called *Scagliuola* or *Scaghiola*. Were it not that the grains are not eaſily freed from the huſks, this plant might be cultivated for the food of man, for its ſeeds yield a good kind of meal. The phalaris has by ſeveral writers been confounded with *argol* or the *lichen rocolla* of Linnæus; but they are very different plants. See Lichen *Rocella* in this Supplement.

CANDLE, a thing ſo univerſally known as to need no particular deſcription. Its uſe, however, is ſo great, that every information tending to its improvement muſt, we ſhould think, be acceptable to our readers. Of the common method of making candles, whether of wax or of tallow, a ſufficient account has been given in the Encyclopædia; but candles of every kind are far from being yet brought to that degree of perfection of which they ſeem ſuſceptible. Thus, for example, the light of a candle, which is ſo exceedingly brilliant when firſt ſnuffed, is very ſpeedily diminiſhed to one-half, and is uſually not more than one-fifth or one-ſixth, before the uneaſineſs of the eye induces us to ſnuff it. Hence it follows, that if candles could be made ſo as not to require ſnuffing, the average quantity of light afforded by the ſame quantity of combuſtible matter would be more than doubled. It may likewiſe be worthy of inquiry, ſince the coſt and duration of candles are eaſily aſcertainable, whether more or leſs light is obtained at the ſame expence during a given time, by burning a number of ſmall candles inſtead of one of greater thickneſs.

To determine this laſt point, a method muſt be found of meaſuring the comparative intenſities of light, for which ſee Photometer in this Supplement. With reſpect to the deſideratum firſt mentioned, we have ſome very ingenious obſervations and well-contrived experiments by Mr Nicholſon, in the ſecond number of his valuable Journal, which we ſhall here inſert nearly in the words of their author.

In every proceſs of combuſtion the free acceſs of air is of the utmoſt conſequence. When a candle has a very ſlender wick, the flame is ſmall and of a brilliant white colour; if the wick be large, the combuſtion is leſs perfect, and the flame brown; and a wick ſtill larger, not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatilized matter, which does not become ignited till it has aſcended towards the point. When the wick is either very large or very long, part of this matter eſcapes combuſtion, and ſhews itſelf in the form of coal or ſmoke. The ſame things take place in the burning of a lamp; but when the wick of a lamp is once adjuſted as to its length, the flame continues nearly in the ſame ſtate for a much longer time than the flame of a candle.

“ Upon comparing a candle with a lamp (ſays Mr Nicholſon), two very remarkable particulars are immediately ſeen. In the firſt place, the tallow itſelf, which remains in the unfuſed ſtate, affords a cup or cavity to hold that portion of melted tallow which is ready to flow into the lighted part of the wick. In the ſecond place, the combuſtion, inſtead of being confined, as in the lamp, to a certain determinate portion of the fibrous matter, is carried, by a ſlow ſucceſſion, through the whole length. Hence ariſes the greater neceſſity for frequent ſnuffing the candle; and hence alſo the ſtation of the freezing point of the fat oil becomes of great conſequence. For it has been ſhewn, that the brilliancy of the flame depends very much on the diameter of the wick being as ſmall as poſſible; and this requiſite will be moſt attainable in candles formed of a material that requires a higher degree of heat to fuſe it. The wick of a tallow candle muſt be made thicker in proportion to the greater fuſibility of the material, which would otherwiſe melt the ſides of the cup, and run over in ſtreams. The flame will therefore be yellow, ſmoky, and obſcure, excepting for a ſhort time immediately after ſnuffing. Tallow melts at the 92d degree of Fahrenheit's thermometer; ſpermaceti at the 133d degree; the fatty matter formed of fleſh, after long immerſion in water, melts at 127 degrees; the *pela* of the Chineſe at 145 degrees; bees-wax at 142 degrees; and bleached wax at 155 degrees. Two of theſe materials are well known in the fabrication of candles. Wax in particular does not afford ſo brilliant a flame as tallow; but, on account of its leſs fuſibility, the wick can be made ſmaller, which not only affords the advantage of a clear perfect flame, but from its flexibility it is diſpoſed to turn on one ſide, and come in contact with the external air, which completely burns the extremity of the wick to white aſhes, and thus performs the office of ſnuffing. We ſee therefore that the important object to ſociety of rendering tallow candles equal to thoſe of wax, does not at all depend on the combuſtibility of the reſpective materials, but upon a mechanical advantage in the cup, which is afforded by the inferior degree of fuſibility in the wax; and that, to obtain this valuable object, one of the following effects muſt be produced: Either the tallow muſt be burned in a lamp, to avoid the gradual progreſſion of the flame along the wick; or ſome means muſt be deviſed to enable the candle to ſnuff itſelf, as the wax candle does; or, laſtly, the tallow itſelf muſt be rendered leſs fuſible by ſome chemical proceſs. I have no great reaſon to boaſt of ſucceſs in the endeavour to effect theſe; but my hope is, that the facts and obſervations here repreſented may conſiderably abridge the labour of others in the ſame purſuit.

“ The makers of thermometers and other ſmall articles with the blow-pipe and lamp, give the preference to tallow inſtead of oil, becauſe its combuſtion is more complete, and does not blacken the glaſs. In this operation the heat of the lamp melts the tallow which is occaſionally brought into its vicinity by the workman. But for the uſual purpoſes of illumination, it cannot be ſuppoſed that a perſon can attend to ſupply the combuſtible matter. Conſiderable difficulties ariſe in the project for affording this gradual ſupply as it may be wanted. A cylindrical piece of tallow was inſerted into a metallic tube, the upper aperture of which was partly cloſed by a ring, and the central part occupied by a metallic piece nearly reſembling that part of the common lamp which carries the wick. In this apparatus the piece laſt deſcribed was intended to anſwer the ſame purpoſe, and was provided with a ſhort wick. The cylinder of tallow was ſupported beneath in ſuch a manner that the metallic tube and other part of this lamp were left to reſt with their whole weight upon the tallow at the ring or contraction of the upper aperture. In this ſituation the lamp was lighted. It burned for ſome time with a very bright clear flame, which, when compared with that of a candle, poſſeſſed the advantage of uniform intenſity, and was much ſuperior to the ordinary flame of a lamp in its colour, and the perfect abſence of ſmell. After ſome minutes it began to decay, and very ſoon afterwards went out. Upon examination, it was found that the metallic piece which carried the wick had fuſed a ſufficient quantity of tallow for the ſupply during the combuſtion; that part of this tallow had flowed beneath the ring, and to other remote parts of the apparatus, beyond the influence of the flame; in conſequence of which, the tube and the cylinder of tallow were faſtened together, and the expected progreſſion of ſupply prevented. It ſeems probable, that in every lamp for burning conſiſtent oils, the material ought to be ſo diſpoſed that it may deſcend to the flame upon the principle of the fountain reſervoir. I ſhall not here ſtate the obſtacles which preſent themſelves in the proſpect of this conſtruction, but ſhall diſmiſs the ſubject by remarking, that a contrivance of this nature would be of the greateſt public utility.

“ The wick of a candle being ſurrounded by the flame, is nearly in the ſituation of a body expoſed to deſtructive diſtillation in a cloſe veſſel. After loſing its volatile products, the carbonaceous reſidue retains its figure, until, by the deſcent of the flame, the external air can have acceſs to its upper extremity. But, in this caſe, the requiſite combuſtion, which might ſnuff it, is not effected: for the portion of oil emitted by the long wick is not only too large to be perfectly burned, but alſo carries off much of the heat of the flame while it aſſumes the elaſtic ſtate. By this diminiſhed combuſtion and increaſed efflux of half-decompoſed oil, a portion of coal or ſoot is depoſited on the upper part of the wick, which gradually accumulates, and at length aſſumes the appearance of a fungus. The candle does not then give more than one-tenth of the light emitted in its beſt ſtate. Hence it is that a candle of tallow cannot ſpontaneouſly ſnuff itſelf. It was not probable that the addition of a ſubſtance containing vital air or oxygene would ſupply that principle at the preciſe period of time required; but as experiment is the teſt of every probability of this nature, I ſoaked a wick of cotton in a ſolution of nitre, then dried it, and made a candle. When this came to be lighted, nothing remarkable happened for a ſhort time; at the expiration of which a decrepitation followed at the lower extremity of the flame, which completely divided the wick where the blackened part commences. The whole of the matter in combuſtion therefore fell off, and the candle was of courſe inſtantly extinguiſhed. Whether this would have happened in all proportions of the ſalt or conſtructions of the candle I did not try, becauſe the ſmell of azote was ſufficiently ſtrong and unpleaſant to forbid the uſe of nitre in the purſuit. From various conſiderations I am diſpoſed to think that the ſpontaneous ſnuffing of candles made of tallow, or other fuſible materials, will ſcarcely be effected but by the diſcovery of ſome material for the wick which ſhall be voluminous enough to abſorb the tallow, and at the ſame time ſufficiently flexible to bend on one ſide.

“ The moſt promiſing ſpeculation reſpecting this moſt uſeful article, ſeems to direct itſelf to the cup which contains the melted tallow. The imperfection of this part has already been noticed, namely, that it breaks down by fuſion, and ſuffers its fluid contents to eſcape. The Chineſe have a kind of candle about half an inch in diameter, which, in the harbour of Canton, is called a *lobchock;* but whether the name be Chineſe, or the corruption of ſome European word, I am ignorant. The wick is of cotton, wrapped round a ſmall ſtick or match of the bamboo cane. The body of the candle is white tallow; but the external part, to the thickneſs of perhaps one-thirtieth of an inch, conſiſts of a waxy matter coloured red. This covering gives a conſiderable degree of ſolidity to the candle, and prevents its guttering, becauſe leſs fuſible than the tallow itſelf. I did not obſerve that the ſtick in the middle was either advantageous or the contrary; and as I now write from the recollection of this object at ſo remote a period as 25 years ago, I can only conjecture that it might be of advantage in throwing up a leſs quantity of oil into the flame than would have been conveyed by a wick of cotton ſufficiently ſtout to have occupied its place unſupported in the axis of the candle.

“ Many years ago I made a candle in imitation of the lobchock. The expedient to which I had recourſe conſiſted in adapting the wick in the uſual pewter mould: wax was then poured in, and immediately afterwards poured out: the film of wax which adhered to the inner ſurface of the mould ſoon became cool, and the candle was completed by filling the mould with tallow. When it was drawn out it was found to be cracked longitudinally on its ſurface, which I attributed to the contraction of the wax, by cooling, being greater than that of the tallow. At preſent I think it equally probable that the cracking might have been occaſioned by too ſudden cooling of the wax before the tallow was poured in; but other avocations prevented the experiments from being varied and repeated. It is probable that the Chineſe external coating may not be formed of pure hard bleached wax.

“ But the moſt deciſive remedy for the imperfection of this cheapeſt, and in other reſpects beſt material, for candles, would undoubtedly be to diminiſh its fuſibility. Various ſubſtances may be combined with tallow, either in the direct or indirect method. In the latter way, by the decompoſition of ſoap, a number of experiments were made by Berthollet, of which an account is inſerted in the Memoirs of the Academy at Paris for the year 1780, and copied into the 26th volume of the *Journal de Phyſique.* None of theſe point directly to the preſent object; beſides which, it is probable that the ſoap made uſe of by that eminent chemiſt was formed not of tallow, but oil. I am not aware of any regular ſeries of experiments concerning the mutual action of fat oils and other chemical agents, more eſpecially ſuch as may be directed to this important object of diminiſhing its ſolubility; for which reaſon I ſhall mention a few experiments made with this view.

1. Tallow was melted in a ſmall ſilver veſſel. Solid tallow ſinks in the fluid, and diſſolves without any remarkable appearance. 2. Gum ſandarach in tears was not diſſolved, but emitted bubbles, ſwelled up, became brown, emitted fumes, and became criſp or friable. No ſolution nor improvement of the tallow. 3. Shell-lac ſwelled up with bubbles, and was more perfectly fuſed than

than the gum ſandarach in the former experiment. When the tallow was poured off, it was thought to congeal rather more ſpeedily. The lac did not appear to be altered. 4. Benzoin bubbled without much ſwelling, was fuſed, and emitted fumes of an agreeable ſmell, though not reſembling the flowers of benzoin. A ſlight or partial ſolution ſeemed to take place. The benzoin was ſofter and of a darker colour than before, and the tallow leſs conſiſtent. 5. Common reſin unites very readily with melted tallow, and forms a more fuſible compound than the tallow itſelf. 6. Camphor melts eaſily in tallow, without altering its appearance. When the tallow is near boiling, camphoric fumes fly off. The compound appeared more fuſible than tallow. 7. The acid or flowers of benzoin diſſolves in great quantities without any ebullition or commotion. Much ſmoke ariſes from the compound, which does not ſmell like the acid of benzoin. Tallow alone does not fume at a low heat, though it emits a ſmell ſomething like that of oil olive. When the proportion of the acid was conſiderable, ſmall needled cryſtals appeared as the temperature diminiſhed. The appearances of ſeparation are different according to the quantity of acid. The compound has the hardneſs and conſiſtence of firm ſoap, and is partially tranſparent. 8. Vitriolated tartar, nitre, white ſugar, cream of tartar, cryſtallized borax, and the ſalt ſold in the markets under the name of ſalt of lemons, but which is ſuppoſed to be the eſſential ſalt of ſorrel, or vegetable alkali ſuperſaturated with acid of ſugar, were reſpectively tried without any obvious mutual action or change of properties in the tallow. 9. Calcined magneſia rendered tallow opaque and turbid, but did not ſeem to diſſolve. Its effect reſembled that of lime.

"It is propoſed to try the oxygenated acetous acid, or radical vinegar; the acid of ants, of ſugar, of borax, of galls, the tanning principle, the ſerous and gelatinous animal matter, the fecula of vegetables, vegetable gluten, bird-lime, and other principles, either by direct or indirect application. The object, in a commercial point of view, is entitled to an extenſive and aſſiduous inveſtigation. Chemiſts in general ſuppoſe the hardneſs or leſs fuſibility of wax to ariſe from oxygen; and to this object it may perhaps be advantageous to direct a certain portion of the inquiry. The metallic ſalts and calces are the combinations from which this principle is moſt commonly obtained; but the combinations of theſe with fat oils have hitherto afforded little promiſe of the improvement here ſought. The ſubject is, however, ſo little known, that experiments of the looſeſt and moſt conjectural kind are by no means to be deſpiſed."

Thus far Mr Nicholſon: but it is probable that many of the advantages which he propoſes by theſe mixtures might be obtained merely by purifying the tallow, and keeping it in that ſtate for a long time expoſed to the air before it be formed into candles. It is certain that tallow is rendered more difficult of fuſion by age; and this is the ſole reaſon that old candles are leſs apt to run, and therefore more valuable than ſuch as have been lately made.

CANIADERAGO, a lake in Otſego co. New-York, nearly as large as Otſego lake, and 6 miles W. of it. A ſtream called Oaks Creek iſſues from it, and falls into Suſquehanna River about 5 miles below Otſego. The beſt cheeſe in the ſtate is ſaid to be made on this creek.—*Morse.*

CANNARES, Indians of the province of Quito, in Peru. They are very well made, and very active; they wear their hair long, which they weave and bind about their heads, in form of a crown. Their clothes are made of wool or cotton, and they wear fine faſhioned boots. Their women are handſome, and fond of the Spaniards; they generally till and manure the ground, whilſt their huſbands at home, card, ſpin, and weave wool and cotton. Their country had many rich gold mines, now drained by the Spaniards. The land bears good wheat and barley, and has fine vineyards. The magnificent palace of *Theomabamba* was in the country of the Cannares.—*ib.*

CANNAVERAL, CAPE, the extreme point of rocks on the E. ſide of the peninſula of E. Florida. It has Moſquitos Inlet N. by W. and a large ſhoal S. by E. This was the bounds of Carolina by charter from Charles II. N. lat. 28. 35. W. long. 81. 9.—*ib.*

CANONGOES, in Bengal, are the regiſters of land and hereditary expounders of the uſages of the country. They have their officers and deputies everywhere; they are not liable to removal; and all papers atteſted by them are received as authentic and deciſive, in all diſputes relative to lands and their boundaries. See *Sir Charles Rouſe Boughton's Diſſertation on the Landed Property of Bengal.*

CANONNICUT *Iſland*, in Newport co. Rhode-Iſland, lies about 3 miles W. of Newport, the S. end of which, (called Beaver Tail, on which ſtands the light-houſe) extends about as far S. as the S. end of Rhode Iſland. It extends N. about 7 miles, its average breadth being about one mile; the E. ſhore forming the W. part of Newport-harbor, and the W. ſhore being about 3 miles from the Narraganſet ſhore. On this point is Jameſtown. It was purchaſed of the Indians in 1657, and in 1678, was incorporated by the name of Jameſtown. The ſoil is luxuriant, producing grain and graſs in abundance.—Jameſtown contains 507 inhabitants, including 16 ſlaves.—*Morse.*

CANONSBURG, a town in Waſhington co. Pennſylvania, on the N. ſide of the W. branch of Chartiers Creek, which runs N. by E. into Ohio River about 5 miles below Pittſburg. In its environs are ſeveral valuable mills. Here are about 50 houſes and an academy; 7 miles N. E. by E. of Waſhington, and 15 S. W. of Pittſburg.—*ib.*

CANTERBURY, a townſhip in Rockingham co. New-Hampſhire, ſituated on the eaſtern bank of Merrimack River; 14 miles N. by W. of Concord, 45 N. W. of Exeter, and 48 from Portſmouth. It contains 1038 inhabitants.—*ib.*

CANTERBURY, a townſhip in Windham co. Connecticut, on the W. ſide of Quinnabaug River which ſeparates it from Plainfield. It is 7 miles E. by S. of Windham, and about 10 or 12 N. of Norwich.—*ib.*

CANTON, a new townſhip in Norfolk co. Maſſachuſetts, incorporated in 1797, it being formerly the northerly part of Stoughton.—*ib.*

CAOUTCHOUC, ELASTIC GUM, or *Indian Rubber*, is a ſubſtance of which a pretty full account has been given in the Encyclopædia. It has there been likewiſe obſerved how uſeful it might be, if we could

Caoutchouc.

form it into catheters and other flexible inſtruments, by diſſolving it in a menſtruum leſs expenſive, or at leaſt more eaſily attained, than ether. Since that article was publiſhed, we have ſeen an account of ſuch a menſtruum in the *Annales de Chimie*, by M. Groſſart (Chirly); and of the expence of that menſtruum, or the difficulty of procuring it, no complaint will be made, when it is known to be nothing more than very hot water.

The author was led to this diſcovery by ſome experiments made with ether on caoutchouc; of which he gives the following account:

“ It appeared, even in my firſt experiments, that I was attempting too much, and giving myſelf uſeleſs trouble, in ſearching for a manner of completely diſſolving the elaſtic gum, ſo that it might be again made up in new forms. I then thought that it would be eaſier to find out a method, as it were, of ſoldering it, and of not acting upon it more than might be neceſſary to cauſe its ſoftened parts to reunite. Experience has ſhewn me, that a ſtrong preſſure made upon two pieces of caoutchouc (when brought to that ſtate of ſoftneſs,) and continued until they are entirely dry, cauſed them to contract ſo ſtrong an adheſion, that the piece, being pulled out till it broke, often broke, not at the united part, but by the ſide of it.

“ By means of ether I immediately ſucceeded in making theſe tubes. The method which appears to me to ſucceed the beſt is, to cut a bottle circularly in a ſpiral ſlip of a few lines in breadth. It is very eaſy to cut a bottle in ſuch a manner as to form a ſingle long ſlip, and thus unneceſſary joinings are avoided.

“ The whole ſlip is to be plunged into ether, until it is ſufficiently ſoftened, which comes to paſs ſooner or later according to the quality of the vitriolic ether that is employed. Half an hour frequently ſuffices; but I have already obſerved, that there is a great diverſity in the manner in which different ſorts of vitriolic ether act, and of which the cauſe is not yet, ſo far as I know, determined.

“ The ſlip being taken out, one of the extremities is to be taken hold of and rolled, firſt upon itſelf at the bottom of the tube, preſſing it; then the rolling is to be continued, mounting ſpirally along the mould, and taking care to lay over and compreſs with the hand every edge, one againſt the other, ſo that there may not be any vacant ſpace, and that all the edges may join exactly. The whole then is to be bound hard with a tape of an inch in width, taking care to turn it the ſame way with the ſlip of elaſtic gum. The tape is to be tied up with packthread, ſo that, by every turn of the packthread joining another, an equal preſſure is given to every part: it is then left to dry, and the tube is made.

“ The bandage is to be taken off with great care, that none of the outward ſurfaces, which may have been lodged within the hollows of the tape (of which the caoutchouc takes the exact impreſſion), may be pulled away. I adviſe the application of a tape before packthread, becauſe, eſpecially in the thinner tubes, we ſhould run the riſk of cutting the caoutchouc, if the packthread were applied immediately upon it.

“ It is eaſy to take off the tube of elaſtic gum which has been formed upon a ſolid mould of one piece; if the mould be made rather conic, it may be made to ſlide off by the ſmaller end; at the worſt, it is eaſily accompliſhed by plunging it into hot water; for it is ſoftened by the heat, and is diſtended; without this precaution it would be ſometimes difficult to draw it off when dry, becauſe, having been applied upon the mould whilſt it had its volume augmented by the interpoſition of the ether, the parts of the caoutchouc are drawn nearer each other, by the evaporation of the interpoſed bodies.

“ The great affinity between theſe two bodies is ſeen by the length of time that the odour of the ether remains, notwithſtanding the great volatility of the latter, and that the apparent dryneſs of the tube ſeems to ſhew that there is none remaining; nevertheleſs, after a certain time, the odour diſappears entirely. One of thoſe tubes, which was made with ether after the method here deſcribed, does not retain the leaſt trace of the ſolvent. It is needleſs to ſay, that it is eaſy to make tubes as thin or as thick as may be judged proper.

“ Although the proceſs that I am now deſcribing is but very little expenſive, yet I have tried to employ other ſolvents in lieu of ether, becauſe it is not to be had in every place, and requires particular care in its preſervation. I have employed, with ſome ſucceſs, the eſſential oils of lavender and of turpentine: both of them ſpeedily dilate the caoutchouc, and are of no great price. The diſagreeable ſmell of the oil of turpentine becomes, perhaps, in proceſs of time, leſs diſagreeable than that of lavender. This laſt is dearer; but the difference is not ſo great as it appears at firſt: for we may make ſome advantage of the oil of lavender that is employed by the following operation: Upon plunging into alcohol the elaſtic tube prepared with the oil of lavender, the alcohol charges itſelf with the oil, and forms a very good lavender-water; the ſame as would be made by an immediate mixture of oil of lavender with ſpirit of wine. Immerſion in this liquor alſo ſerves to haſten the drying of the caoutchouc inſtruments thus made by means of eſſential oils. I have made tubes with the oils of turpentine and of lavender; both are much ſlower in evaporating than ether. The oil of turpentine particularly appeared to me always to have a kind of ſtickineſs, and I know not as yet that we have any means whereby to get ſpeedily rid of its ſmell.

“ Nevertheleſs there is a ſolvent which has not that inconvenience; it is cheaper, and may eaſily be procured by every one: this ſolvent is *water*. I conceive it will appear ſtrange to mention water as a ſolvent of elaſtic gum, that liquid having been always ſuppoſed to have no action upon it. I myſelf reſiſted the idea; but reflecting that ether, by being ſaturated with water, is the better enabled to act on caoutchouc, and that this gum when plunged into boiling water becomes more tranſparent at the edges, I preſumed that this effect was not due ſimply to the dilation of its volume by the heat. I thought that, at that temperature, ſome action might take place, and that a long-continued ebullition might produce more ſenſible effects. I was not diſappointed in my expectations, and one of thoſe tubes was prepared without any other ſolvent than water and heat. I proceeded in the ſame manner as with ether: the elaſtic gum dilates but very little in boiling water; it becomes whitiſh, but recovers its colour again by drying it in the air and light. It is ſufficiently prepared for uſe when it has been a quarter of an hour in boiling water: by this time its edges are ſometimes tranſparent. It is to be turned ſpirally round the mould, in the manner we deſcribed before, and replunged frequently into the boiling water, during the time that is employed in forming the tube, to the end that the edges may be diſpoſed to unite together. When the whole is bound with packthread, it is to be kept ſome hours in boiling water; after which it is to be dried, ſtill keeping on the binding.

“ If we wiſh to be more certain that the connection is perfect, the ſpiral may be doubled; but we muſt always avoid placing the exterior ſurfaces of the ſlips one upon the other, as thoſe ſurfaces are the parts which moſt reſiſt the action of ſolvents. This precaution is leſs neceſſary when ether is employed, on account of its great action upon the caoutchouc.

“ It might be feared that the action of water upon caoutchouc would deprive us of the advantages which might otherwiſe be expected; but theſe fears will be removed, if we conſider that the affinities differ according to the temperatures; that it is only at a very high temperature that water exerciſes any ſenſible action upon caoutchouc. I can affirm, that at 120° of Reaumur's thermometer (302° of Fahrenheit) this affinity is not ſuch as that the water can give a liquid form to caoutchouc; and it does not appear that we have any thing to fear in practice from a combination between theſe two bodies, which, though it really is a true ſolution, does not take place in any ſenſible degree but at a high temperature. It is therefore at preſent eaſy to make of caoutchouc whatever inſtruments it may be advantageous to have of a flexible, ſupple, and elaſtic ſubſtance, which is impermeable to water at the temperature of our atmoſphere, and reſiſts the action of acids as well as that of moſt other ſolvents. As to the durability of theſe inſtruments, few ſubſtances promiſe more than this, becauſe it may be ſoldered afreſh in a damaged part. Any woven ſubſtance may be covered with it; it is only required that the ſubſtance ſhould be of a nature not to be acted upon during the preparation, either by ether or by boiling water; for theſe two agents are thoſe which appear to me to merit the preference. Artiſts will frequently find an advantage in employing ether, as it requires leſs time; ſo that a perſon may make, in a ſingle day, any tube he may have occaſion for. The expence of ether is very little, ſince it is needful only to diſpoſe the caoutchouc to adhere; and being brought into that ſtate, the caoutchouc may be kept in a veſſel perfectly well cloſed. It would alſo diminiſh the expence of the ether if, inſtead of waſhing it with a large quantity of water, there ſhould be added to it only as much water as it can take up.”

CAP and BUTTON, are two ſmall iſlands, or rather rocks, lying in longitude 105° 48′ 30″ eaſt; and in latitude, the former 5° 58′ 30″, the latter 5° 49′ ſouth. They were viſited by ſome of the perſons attending Lord Macartney on his embaſſy to China; and are thus deſcribed by Sir George Staunton.

“ At a little diſtance they might be miſtaken for the remains of old caſtles, mouldering into heaps of ruins, with tall trees already growing upon the tops; but at a nearer view, they betrayed evident marks of a volcanic origin. Exploſions from ſubterraneous fires, produce, for the moſt part, hills of a regular ſhape, and terminating in truncated cones; but when from a ſubaqueous volcano eruptions are thrown up above the ſurface of the ſea, the materials, falling back into the water, are more irregularly diſperſed, and generally leave the ſides of the new creation naked and miſhapen, as in the inſtance of AMSTERDAM, and of thoſe ſmaller ſpots called, from ſome reſemblance in ſhape, the Cap and Button.

“ In the Cap were found two caverns, running horizontally into the ſide of the rock; and in theſe were a number of thoſe birds neſts ſo much prized by the Chineſe epicures. They ſeemed to be compoſed of fine filaments cemented together by a tranſparent viſcous matter, not unlike what is left by the foam of the ſea upon ſtones alternately covered by the tide, or thoſe gelatinous animal ſubſtances found floating on every coaſt. The neſts adhere to each other, and to the ſides of the cavern, moſtly in rows, without any break or interruption. The birds that build theſe neſts are ſmall grey ſwallows, with bellies of a dirty white. They were flying about in conſiderable numbers; but they were ſo ſmall, and their flight ſo quick, that they eſcaped the ſhot fired at them. The ſame neſts are ſaid alſo to be found in deep caverns, at the foot of the higheſt mountains in the middle of Java, and at a diſtance from the ſea, from which the birds, it is thought, derive no materials, either for their food or the conſtruction of their neſts; as it does not appear probable they ſhould fly, in ſearch of either, over the intermediate mountains, which are very high, or againſt the boiſterous winds prevailing thereabouts. They feed on inſects, which they find hovering over ſtagnated pools between the mountains, and for catching which their wide opening beaks are particularly adapted. They prepare their neſts from the beſt remnants of their food. Their greateſt enemy is the kite, who often intercepts them in their paſſage to and from the caverns, which are generally ſurrounded with rocks of grey limeſtone or white marble. The neſts are placed in horizontal rows at different depths, from 50 to 500 feet. The colour and value of the neſts depend on the quantity and quality of the inſects caught, and perhaps alſo on the ſituation where they are built. Their value is chiefly determined by the uniform fineneſs and delicacy of their texture; thoſe that are white and tranſparent being moſt eſteemed, and fetching often in China their weight in ſilver. Theſe neſts are a conſiderable object of traffic among the Javaneſe, and many are employed in it from their infancy. The birds having ſpent near two months in preparing their neſts, lay each two eggs, which are hatched in about fifteen days. When the young birds become fledged, it is thought time to ſeize upon their neſts, which is done regularly thrice a year, and is effected by means of ladders of bamboo and reeds, by which the people deſcend into the cavern; but when it is very deep, rope ladders are preferred. This operation is attended with much danger; and ſeveral break their necks in the attempt. The inhabitants of the mountains generally employed in it begin always by ſacrificing a buffalo; which cuſtom is conſtantly obſerved by the Javaneſe on the eve of every extraordinary enterpriſe. They alſo pronounce ſome prayers, anoint themſelves with ſweet-ſcented oil, and ſmoke the entrance of the cavern with gum-benjamin. Near ſome of thoſe caverns a tutelar goddeſs is worſhipped, whoſe prieſt burns incenſe, and lays his protecting hands on every perſon preparing to deſcend into the cavern. A flambeau is carefully prepared at the ſame time, with a gum which exudes from a tree growing in the vicinity, and is not eaſily extinguiſhed by fixed air or ſubterraneous vapours. The ſwallow, which builds thoſe neſts, is deſcribed as not having its tail feathers marked with white ſpots, which is a character attributed to it by Linnæus; and it is poſſible that there are two ſpecies or varieties of the ſwallow, whoſe neſts are alike valuable." See *Birds-Neſts*, Encycl.

CAPE of Good Hope. See *Good Hope*, both in *Encycl.* and this *Supplement.*

CAPE ST. ANDREWS, on the coaſt of Paraguay, or La Plata, S. America. S. lat. 38. 50. W. long. 59. 46.—*Morse.*

Cape St. Antonio, or *Anthonio*, is the point of land on the ſouthern ſide of La Plata River in S. America, which, with Cape St Mary on the northward, forms the mouth of that river. S. lat. 36. 32. W. long. 56. 34.—*ib.*

Cape St. Augustine, on the coaſt of Brazil, S. America, lies ſouthward of Pernambuco. S. lat. 10. 15. W. long. 35. 13.—*ib.*

Cape Blow-me-down, which is the ſouthern ſide of the entrance from the bay of Fundy into the Baſin of Minas, is the eaſternmoſt termination of a range of mountains, extending about 80 or 90 miles to the gut of Annapolis; bounded N. by the ſhores of the bay of Fundy, and S. by the ſhores of Annapolis river. —*ib.*

Cape Cod, anciently called *Mallebarre*, by the French, is the S. eaſtward point of the bay of Maſſachuſetts, oppoſite Cape Ann. N. lat. 42. 4. W. long. from Greenwich, 70. 14.—*ib.*

Cape Elizabeth, a head-land and townſhip in Cumberland co. diſtrict of Maine. The cape lies in N. lat. 43. 33. E. by S. from the centre of the town 9 miles; about 20 S. weſterly of Cape Small Point, and 12 N. E. from the mouth of Saco River. The town has Portland on the N. E. and Scarborough S. W. and contains 1355 inhabitants. It was incorporated in 1765, and lies 126 miles N. E. of Boſton.—*ib.*

Cape Fear, is the ſouthern point of Smith's Iſland which forms the mouth of Cape Fear River into two channels, on the coaſt of N. Carolina; S. W. of Cape Look-Out, and remarkable for a dangerous ſhoal called the Frying Pan, from its form. Near this cape is Johnſon's Fort, in Brunſwick co. and diſtrict of Wilmington. N. lat. 33. 32. W. long. 78. 25.

Cape Fear *River* more properly Clarendon, affords the beſt navigation in N. Carolina. It opens to the Atlantic ocean by two channels. The S. weſtern and largeſt channel between the S. W. end of Smith's Iſland at Bald Head, where the light-houſe ſtands, and the E. end of Oakes Iſland, S. W. from Fort Johnſton. The new inlet is between the ſea-coaſt and the N. E. end of Smith's Iſland. It will admit veſſels drawing 10 or 11 feet, and is about 3 miles wide at its entrance, having 18 feet water at full tides over the bar. It continues its breadth to the flats, and is navigable for large veſſels 21 miles from its mouth, and 14 from Wilmington; to which town veſſels drawing 10 or 12 feet can reach without any riſk. As you aſcend this river you leave Brunſwick on the left, and Wilmington on the right. A little above Wilmington, the river divides into N. E. and N. W. branches. The former is broader than the latter, but is neither ſo deep nor ſo long. The N. W. branch riſes within a few miles of the Virginia line, and is formed by the junction of Haw and Deep rivers. Its general courſe is S. eaſterly. Sea veſſels can go 25 miles above Wilmington, and large boats 90 miles, to Fayetteville. The N. E. branch joins the N. W. branch a little above Wilmington, and is navigable by ſea veſſels 20 miles above that town, and by large boats to South Waſhington, 40 miles further, and by rafts to Sarecto, which is nearly 70 miles. The whole length of Cape Fear river is about 200 miles.—*ib.*

Cape May, is the S. weſternmoſt point of the ſtate of New-Jerſey, and of the county to which it gives name. N. lat. 39. W. long. 75. 2. It lies 20 miles N. E. from Cape Henlopen, which forms the S. W. point of the mouth of Delaware bay, as Cape May does the N. E.—*ib.*

Cape May *Co.* ſpreads northward, around the cape of its name, is a healthy, ſandy tract of country, of ſufficient fertility to give ſupport to 2571 induſtrious and peaceable inhabitants. The county is divided into Upper, Middle, and Lower precincts.—*ib.*

CAPITAL of a Bastion, is an imaginary line dividing any work into two equal and ſimilar parts; or a line drawn from the angle of the polygon to the point of the baſtion, or from the point of the baſtion to the middle of the gorge.

CAPRA, or the She-goat, a name given to the ſtar Capella, on the left ſhoulder of Auriga, and ſometimes to the conſtellation Capricorn. Some again repreſent Capra as a conſtellation in the northern hemiſphere, conſiſting of three ſtars, compriſed between the 45th and 55th degree of latitude.—The poets fable her to be Amalthea's goat, which ſuckled Jupiter in his infancy.

CAPUT Draconis, or *Dragon's Head*, a name given by ſome to a fixed ſtar of the firſt magnitude, in the head of the conſtellation Draco.

CARACCAS, a province of Terra Firma, S. America, lying on the ſouthern coaſt of the Caribbean Sea. This coaſt is bordered in its greateſt length by a chain of mountains, running E. and W. and divided into many fruitful vallies, whoſe direction and opening are towards the N. It has maritime fortified towns, Puerto Cabelo, and La Guayra. The Dutch carry thither to the Spaniards all ſorts of European goods, eſpecially linen, making vaſt returns of ſilver and cocoa. The cocoa tree grows here in abundance. There are from 500 to 2000 trees in a walk, or plantation. Theſe nuts are paſſed for money, and are uſed as ſuch in the bay of Campeachy. N. lat. 10. 12. W. long. 67. 10.—*Morse.*

CARANGAS, a province and juriſdiction under the biſhop of Plata, and 70 leagues W. of that city, in Peru, very barren in corn and grain, &c. but abounding in cattle. Here are a great number of ſilver mines conſtantly worked, among which that called Tureo, and by the miners Machacado, is very remarkable. The fibres of the ſilver forming an admirable intermixture with the ſtone; ſuch mines are generally the richeſt. There are other maſſes of ſilver in this province equally remarkable, being found in the barren ſandy deſarts, where they find, by digging only, detached lumps it is with pleaſure that we can ſay, that we were told by the editor, that this work was prompted in a great meaſure by what has been delivered in the *Encyclopædia* in the articles Roof and *Strength of Materials*. It abounds more in important and new obſervations than any book of the kind that we are acquainted with. We again call on ſuch as have given a ſcientific attention to this ſubject, and pray that they would render a meritorious ſervice to their country by imparting the reſult of their reſearches. The very limited nature of this work does not allow us to treat the ſubject in detail; and we muſt confine our obſervations to the fundamental and leading propoſitions.

4 Theory, founded on what.

The theory (ſo to term it) of carpentry is founded on two diſtinct portions of mechanical ſcience, namely, a knowledge of the ſtrains to which framings of timber are expoſed, and a knowledge of their *relative* ſtrength.

We ſhall therefore attempt to bring into one point of view the propoſitions of mechanical ſcience that are more immediately applicable to the art of carpentry, and are to be found in various articles of our work, particularly Roof and *Strength of Materials*. From theſe propoſitions we hope to deduce ſuch principles as ſhall enable an attentive reader to comprehend diſtinctly what is to be aimed at in framing timber, and how to attain this object with certainty: and we ſhall illuſtrate and confirm our principles by examples of pieces of carpentry which are acknowledged to be excellent in their kind.

5 Compoſition and reſolution of forces

The moſt important propoſition of general mechanics to the carpenter is that which exhibits the compoſition and reſolution of forces; and we beg our practical readers to endeavour to form very diſtinct conceptions of it, and to make it very familiar to their mind. When accommodated to their chief purpoſes, it may be thus expreſſed:

Plate VIII.

1. If a body, or any part of a body, be at once preſſed in the two directions AB, AC (fig. 1.), and if the intenſity or force of thoſe preſſures be in the proportion of theſe two lines, the body is affected in the ſame manner as if it were preſſed by a ſingle force acting in the direction AD, which is the diagonal of the parallelogram ABDC formed by the two lines, and whoſe intenſity has the ſame proportion to the intenſity of each of the other two that AD has to AB or AC.

6 Illuſtrated by experiment.

Such of our readers as have *ſtudied* the laws of motion, know that this is fully demonſtrated. We refer them to the article Mechanics, n° 5, &c. where it is treated at ſome length. Such as wiſh for a very accurate view of this propoſition, will do well to read the demonſtration given by D. Bernoulli, in the firſt volume of the *Comment. Petropol.* and the improvement of this demonſtration by D'Alembert in his *Opuſcles*, and in the *Comment. Taurinenſ.* The practitioner in carpentry will get more uſeful confidence in the doctrine, if he will ſhut his book, and verify the theoretical demonſtrations by actual experiments. They are remarkably eaſy and convincing. Therefore it is our requeſt that the artiſt, who is not ſo habitually acquainted with the ſubject, do not proceed further till he has made it quite familiar to his thoughts. Nothing is ſo conducive to this as the actual experiment; and ſince this only requires the trifling expence of two ſmall pulleys and a few yards of whipcord, we hope that none of our practical readers will omit it: They will thank us for this injunction.

2. Let the threads A*d*, AF*b*, and AE*c* (fig. 2), have the weights *d*, *b*, and *c*, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus the knot A will be drawn in the directions AB, AC, and AK. If the ſum of the weights *b* and *c* be greater than the ſingle weight *d*, the aſſemblage will of itſelf ſettle in a certain determined form; if you pull the knot A out of its place, it will always return to it again, and will reſt in no other poſition. For example, if the three weights are equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle oppoſite to the thread ſtretched by five pounds will always be ſquare, &c. When the knot A is thus in equilibrio, we muſt infer, that the action of the weight *d*, in the direction A *d*, is in direct oppoſition to the combined action of *b*, in the direction AB, and of *c*, in the direction AC. Therefore, if we produce *d* A to any point D, and take AD to repreſent the magnitude of the force, or preſſure exerted by the weight *d*, the preſſures exerted on A by the weights *b* and *c*, in the directions AB, AC, are in fact equivalent to a preſſure acting in the direction AD, whoſe intenſity we have repreſented by AD. If we now meaſure off by a ſcale on AF and AE the lines AB and AC, having the ſame proportions to AD that the weights *b* and *c* have to the weight *d*, and if we draw DB and DC, we ſhall find DC to be equal and parallel to AB, and DB equal and parallel to AC; ſo that AD is the diagonal of a parallelogram ABDC. We ſhall find this always to be the caſe, whatever are the weights made uſe of; only we muſt take care that the weight which we cauſe to act without the intervention of a pulley be leſs than the ſum of the other two: if any one of the weights exceeds the ſum of the other two, it will prevail, and drag them along with it.

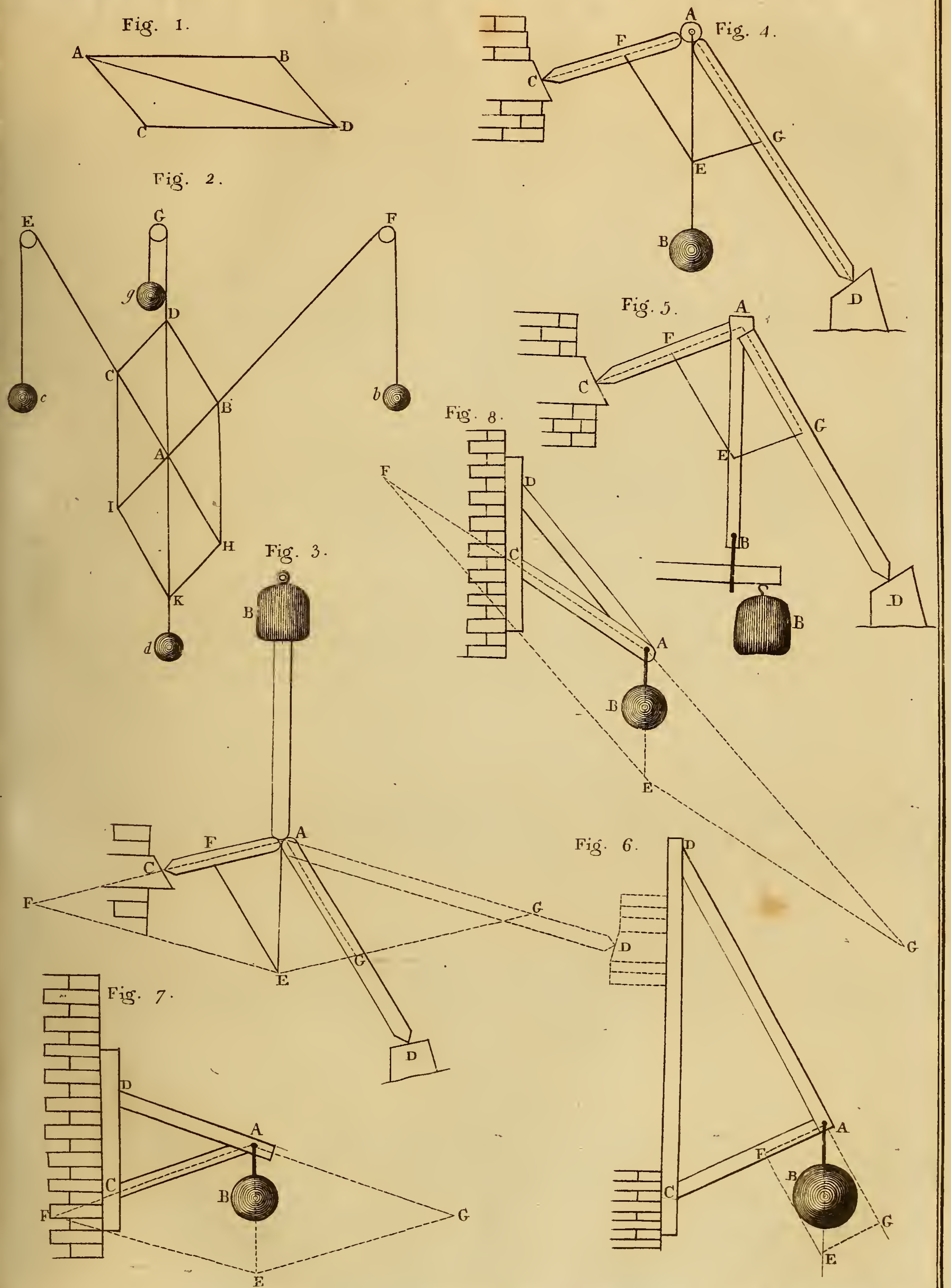
Now ſince we know that the weight *d* would juſt balance an equal weight *g* pulling directly upwards by the intervention of the pulley G; and ſince we ſee that it juſt balances the weights *b* and *c* acting in the directions AB, AC, we muſt infer, that the knot A is affected in the ſame manner by thoſe two weights, or by the ſingle weight *g*; and therefore, that *two preſſures, acting in the directions, and with the intenſities,* AB, AC, *are equivalent to a ſingle preſſure having the direction and proportion of* AD. In like manner, the preſſures AB, AK, are equivalent to AH, which is equal and oppoſite to AC. Alſo AK and AC are equivalent to AI, which is equal and oppoſite to AB.

7 Conſidere more part cularly.

We ſhall conſider this combination of preſſures a little more particularly.

Suppoſe an upright beam BA (fig. 3.) puſhed in the direction of its length by a load B, and abutting on the ends of two beams, AC, AD, which are firmly reſiſted at their extreme points C and D, which reſt on two blocks, but are nowiſe joined to them: theſe two beams can reſiſt no way but in the directions CA, DA; and therefore the preſſures which they ſuſtain from the beam BA are in the directions AC, AD. We wiſh to know how much each ſuſtains? Produce BA to E, taking AE from a ſcale of equal parts, to repreſent the number of tons or pounds by which BA is preſſed. Draw

CARPENTRY PLATE VIII.



J. Bower Sculp.t

Draw EF and EG parallel to AD and AC; then AF, meaſured on the ſame ſcale, will give us the number of pounds by which AC is ſtrained or cruſhed, and AG will give the ſtrain on AD.

It deſerves particular remark here, that the length of AC or AD has no influence on the ſtrain, ariſing from the thruſt of BA, while the directions remain the ſame. The effects, however, of this ſtrain are modified by the length of the piece on which it is exerted. This ſtrain compreſſes the beam, and will therefore compreſs a beam of double length twice as much. This may change the form of the aſſemblage. If AC, for example, be very much ſhorter than AD, it will be much leſs compreſſed: The line CA will turn about the centre C, while DA will hardly change its poſition; and the angle CAD will grow more open, the point A ſinking down. The artiſt will find it of great conſequence to pay a very minute attention to this circumſtance, and to be able to ſee clearly the change of ſhape which neceſſarily reſults from theſe mutual ſtrains. He will ſee in this the cauſe of failure in many very great works.—By thus changing ſhape, ſtrains are often produced in places where there were none before, and frequently of the very worſt kind, tending to break the beams acroſs.

The dotted lines of this figure ſhew another poſition of the beam AD′. This makes a prodigious change, not only in the ſtrain on AD′, but alſo in that on AC. Both of them are much increaſed; AG is almoſt doubled, and AF is four times greater than before. This addition was made to the figure, to ſhew what enormous ſtrains may be produced by a very moderate force AE, when it is exerted on a very obtuſe angle.

The 4th and 5th figures will aſſiſt the moſt uninſtructed reader in conceiving how the very ſame ſtrains AF, AG, are laid on theſe beams, by a weight ſimply hanging from a billet reſting on A, preſſing hard on AD, and alſo leaning a little on AC; or by an upright piece AE, joggled on the two beams AC, AD, and performing the office of an ordinary king-poſt. The reader will thus learn to call off his attention from the means by which the ſtrains are produced, and learn to conſider them abſtractedly, merely as ſtrains, in whatever ſituation he finds them, and from whatever cauſe they ariſe.

We preſume that every reader will perceive, that the proportions of theſe ſtrains will be preciſely the ſame if every thing be inverted, and each beam be drawn or pulled in the oppoſite direction. In the ſame way that we have ſubſtituted a rope and weight in fig. 4. or a king-poſt in fig. 5. for the loaded beam BA of fig. 3. we might have ſubſtituted the framing of fig. 6. which is a very uſual practice. In this framing, the batten DA is ſtretched by a force AG, and the piece AC is compreſſed by a force AF. It is evident, that we may employ a rope, or an iron rod hooked on at D, in place of the batten DA, and the ſtrains will be the ſame as before.

This ſeemingly ſimple matter is ſtill full of inſtruction; and we hope that the well-informed reader will pardon us, though we dwell a little longer on it for the ſake of the young artiſt.

By changing the form of this framing, as in fig. 7. we produce the ſame ſtrains as in the diſpoſition repreſented by the dotted lines in fig. 3. The ſtrains on both the battens AD, AC, are now greatly increaſed.

The ſame conſequences reſult from an improper change of the poſition of AC. If it is placed as in fig. 8. the ſtrains on both are vaſtly increaſed. In ſhort, the rule is general; that the more open we make the angle againſt which the puſh is exerted, the greater are the ſtrains which are brought on the ſtruts or ties which form the ſides of the angle.

The reader may not readily conceive the piece AC of fig. 8. as ſuſtaining a compreſſion; for the weight B appears to hang from AC as much as from AD. But his doubts will be removed by conſidering whether he could employ a rope in place of AC. He cannot: But AD may be exchanged for a rope. AC is therefore a ſtrut, and not a tie.

In fig. 9. AD is again a ſtrut, butting on the block D, and AC is a tie: and the batten AC may be replaced by a rope. While AD is compreſſed by the force AG, AC is ſtretched by the force AF.

If we give AC the poſition repreſented by the dotted lines, the compreſſion of AD is now AG′, and the force ſtretching AC′ is now AF′; both much greater than they were before. This diſpoſition is analogous to fig. 8. and to the dotted lines in fig. 3. Nor will the young artiſt have any doubts of AC′ being on the ſtretch, if he conſider whether AD can be replaced by a rope. It cannot, but AC′ may; and it is therefore not compreſſed, but ſtretched.

In fig. 10. all the three pieces, AC, AD, and AB, are ties, on the ſtretch. This is the complete inverſion of fig. 3.; and the dotted poſition of AC′ induces the ſame changes in the forces AF′, AG′, as in fig. 3.

Thus have we gone over all the varieties which can happen in the bearings of three pieces on one point. All calculations about the ſtrength of carpentry are reduced to this caſe: for when more ties or braces meet in a point (a thing that rarely happens), we reduce them to three, by ſubſtituting for any two the force which reſults from their combination, and then combining this with another; and ſo on.

The young artiſt muſt be particularly careful not to miſtake the kind of ſtrain that is exerted on any piece of the framing, and ſuppoſe a piece to be a brace which is really a tie. It is very eaſy to avoid all miſtakes in this matter by the following rule, which has no exception.

8
Rule for diſtinguiſhing the caſes of compreſſion and extenſion.

Take notice of the direction in which the piece acts from which the ſtrain proceeds. Draw a line in that direction *from* the point on which the ſtrain is exerted; and let its length (meaſured on ſome ſcale of equal parts) expreſs the magnitude of this action in pounds, hundreds, or tons. From its *remote* extremity draw lines parallel to the pieces on which the ſtrain is exerted. The line parallel to one piece will neceſſarily cut the other, or its direction produced: If it cut the piece itſelf, that piece is compreſſed by the ſtrain, and it is performing the office of a ſtrut or brace: if it cut its direction produced, the piece is ſtretched, and it is a tie. In ſhort, the ſtrains on the pieces AC, AD, are to be eſtimated in the direction of the points F and G *from* the ſtrained point A. Thus, in fig. 3. the upright piece BA, loaded with the weight B, preſſes the point A in the direction AE: ſo does the rope AB in the other figures, or the batten AB in fig. 5.

In general, if the ſtraining piece is within the angle formed ſormed by the pieces which are ſtrained, the ſtrains which they ſuſtain are of the oppoſite kind to that which it exerts. If it be puſhing, they are drawing; but if it be within the angle formed by their directions produced, the ſtrains which they ſuſtain are of the ſame kind. All the three are either drawing or preſſing. If the ſtraining piece lie within the angle formed by one piece and the produced direction of the other, its own ſtrain, whether compreſſion or extenſion, is of the ſame kind with that of the moſt remote of the other two, and oppoſite to that of the neareſt. Thus, in fig. 9. where AB is drawing, the remote piece AC is alſo drawing, while AD is puſhing or reſiſting compreſſion.

In all that has been ſaid on this ſubject, we have not ſpoken of any joints. In the calculations with which we are occupied at preſent, the reſiſtance of joints has no ſhare; and we muſt not ſuppoſe that they exert any force which tends to prevent the angles from changing. The joints are ſuppoſed perfectly flexible, or to be like compaſs joints; the pin of which only keeps the pieces together when one or more of the pieces draws or pulls. The carpenter muſt always ſuppoſe them all compaſs joints when he calculates the thruſts and draughts of the different pieces of his frames. The ſtrains on joints, and their power to produce or balance them, are of a different kind, and require a very different examination.

9
General expreſſion of the magnitude of the ſtrain.

Seeing that the angles which the pieces make with each other are of ſuch importance to the magnitude and the proportion of the excited ſtrains, it is proper to find out ſome way of readily and compendiouſly conceiving and expreſſing this analogy.

In general, the ſtrain on any piece is proportional to the ſtraining force. This is evident.

Secondly, the ſtrain on any piece AC is proportional to the ſine of the angle which the ſtraining force makes with the other piece directly, and to the ſine of the angle which the pieces make with each other inverſely.

For it is plain, that the three preſſures AE, AF, and AG, which are exerted at the point A, are in the proportion of the lines AE, AF, and FE (becauſe FE is equal to AG). But becauſe the ſides of a triangle are proportional to the ſines of the oppoſite angles, the ſtrains are proportional to the ſines of the angles AFE, AEF, and FAE. But the ſine of AFE is the ſame with the ſine of the angle CAD, which the two pieces AC and AD make with each other; and the ſine of AFE is the ſame with the ſine of EAD, which the ſtraining piece BA makes with the piece AC. Therefore we have this analogy, $\text{Sin. CAD} : \text{Sin. EAD} = AE : AF$, and $AF = AE \times \frac{\text{Sin. EAD}}{\text{Sin. CAD}}$.—Now the ſine of angles are moſt conveniently conceived as decimal fractions of the radius, which is conſidered as unity. Thus, *Sin.* 30° is the ſame thing with 0,5, or $\frac{1}{2}$; and ſo of others. Therefore, to have the ſtrain on AC, ariſing from any load AE acting in the direction AE, multiply AE by the ſine of EAD, and divide the product by the ſine of CAD.

This rule ſhews how great the ſtrains muſt be when the angle CAD becomes very open, approaching to 180 degrees. But when the angle CAD becomes very ſmall, its ſine (which is our diviſor) is alſo very ſmall; and we ſhould expect a very great quotient in this caſe alſo. But we muſt obſerve, that in this caſe the ſine of EAD is alſo very ſmall; and this is our multiplier. In ſuch a caſe, the quotient cannot exceed unity.

But it is unneceſſary to conſider the calculation by the tables of ſines more particularly. The angles are ſeldom known any otherwiſe but by drawing the figure of the frame of carpentry. In this caſe, we can always obtain the meaſures of the ſtrains from the ſame ſcale, with equal accuracy, by drawing the parallelogram AFCG.

10
Strains pr
pagated t
the points
of ſupport

Hitherto we have conſidered the ſtrains excited at A only as they affect the pieces on which they are exerted. But the pieces, in order to ſuſtain, or be ſubject to, any ſtrain, muſt be ſupported at their ends C and D; and we may conſider them as mere intermediums, by which theſe ſtrains are made to act on thoſe points of ſupport: Therefore AF and AG are alſo meaſures of the forces which preſs or pull at C and D. Thus we learn the ſupports which muſt be found for theſe points. Theſe may be infinitely various. We ſhall attend only to ſuch as ſomehow depend on the framing itſelf.

11
Action of ſtraining beam.

Such a ſtructure as fig. 11. very frequently occurs, where a beam BA is ſtrongly preſſed to the end of another beam AD, which is prevented from yielding, both becauſe it lies on another beam HD, and becauſe its end D is hindered from ſliding backwards. It is indifferent from what this preſſure ariſes: we have repreſented it as owing to a weight hung on at B, while B is withheld from yielding by a rod or rope hooked to the wall. The beam AD may be ſuppoſed at full liberty to exert all its preſſure on D, as if it were ſupported on rollers lodged in the beam HD; but the loaded beam BA preſſes both on the beam AD and on HD. We wiſh only to know what ſtrain is borne by AD?

All bodies act on each other in the direction perpendicular to their touching ſurfaces; therefore the ſupport given by HD is in a direction perpendicular to it. We may therefore ſupply its place at A by a beam AC, perpendicular to HD, and firmly ſupported at C. In this caſe, therefore, we may take AE, as before, to repreſent the preſſure exerted by the loaded beam, and draw EG perpendicular to AD, and EF parallel to it, meeting the perpendicular AC in F. Then AG is the ſtrain compreſſing AD, and AF is the preſſure on the beam HD.

12
The form
of the abut
ting joint
of no grea
importance.

It may be thought, that ſince we aſſume as a principle that the mutual preſſures of ſolid bodies are exerted perpendicular to their touching ſurfaces, this balance of preſſures, in framings of timbers, depends on the directions of their butting joints: but it does not, as will readily appear by conſidering the preſent caſe. Let the joint or abutment of the two pieces BA, AD be mitred, in the uſual manner, in the direction *f*A*ft*. Therefore, if A *e* be drawn perpendicular to A*f*, it will be the direction of the actual preſſure exerted by the loaded beam BA on the beam AD. But the reaction of AD, in the oppoſite direction A *t*, will not balance the preſſure of BA; becauſe it is not in the direction preciſely oppoſite. BA will therefore ſlide along the joint, and preſs on the beam HD. AE repreſents the load on the mitre joint A. Draw E *e* perpendicular to A *e*, and E*f* parallel to it. The preſſure AE will be balanced by the reactions *e* A and *f*A: or, the preſſure AE produces the preſſures $\mathrm{A}e$ and $\mathrm{A}f$; of which $\mathrm{A}f$ muſt be reſiſted by the beam HD, and $\mathrm{A}e$ by the beam AD. The preſſure $\mathrm{A}f$ not being perpendicular to HD, cannot be fully reſiſted by it; becauſe (by our aſſumed principle) it reacts only in a direction perpendicular to its ſurface. Therefore draw fp, fi parallel to HD, and perpendicular to it. The preſſure $\mathrm{A}f$ will be reſiſted by HD with the force $p\mathrm{A}$; but there is required another force $i\mathrm{A}$, to prevent the beam BA from ſlipping outwards. This muſt be furniſhed by the reaction of the beam DA.—In like manner, the other force $\mathrm{A}e$ cannot be fully reſiſted by the beam AD, or rather by the prop D, acting by the intervention of the beam; for the action of that prop is exerted through the beam in the direction DA. The beam AD, therefore, is preſſed to the beam HD by the force $\mathrm{A}e$, as well as by $\mathrm{A}f$. To find what this preſſure on HD is, draw eg perpendicular to HD, and eo parallel to it, cutting EG in r. The forces $g\mathrm{A}$ and $o\mathrm{A}$ will reſiſt, and balance $\mathrm{A}e$.

Thus we ſee, that the two forces $\mathrm{A}e$ and $\mathrm{A}f$, which are equivalent to AE, are equivalent alſo to $\mathrm{A}p$, $\mathrm{A}i$, $\mathrm{A}o$, and $\mathrm{A}g$. But becauſe $\mathrm{A}f$ and $e\mathrm{E}$ are equal and parallel, and $\mathrm{E}r$ and fi are alſo parallel, as alſo er and fp, it is evident, that if is equal to $r\mathrm{E}$, or to $o\mathrm{F}$, and $i\mathrm{A}$ is equal to re, or to $\mathrm{G}g$. Therefore the four forces $\mathrm{A}g$, $\mathrm{A}o$, $\mathrm{A}p$, $\mathrm{A}i$, are equal to AG and AF. Therefore AG is the compreſſion of the beam AD, or the force preſſing it on D, and A F is the force preſſing it on the beam HD. The proportion of theſe preſſures, therefore, is not affected by the form of the joint.

This remark is important; for many carpenters think the form and direction of the butting joint of great importance; and even the theoriſt, by not proſecuting the general principle through *all* its conſequences, may be led into an error. The form of the joint is of no importance, in as far as it affects the ſtrains in the direction of the beams; but it is often of great conſequence, in reſpect to its own firmneſs, and the effect it may have in bruiſing the piece on which it acts, or being crippled by it.

13 Origin of the ſtrain on a tie-beam.

The ſame compreſſion of AB, and the ſame thruſt on the point D by the intervention of AD, will obtain, in whatever way the original preſſure on the end A is produced. Thus ſuppoſing that a chord is made faſt at A, and pulled in the direction AE, and with the ſame force, the beam AD will be equally compreſſed, and the prop D muſt react with the ſame force.

But it often happens that the obliquity of the preſſure on AD, inſtead of compreſſing it, ſtretches it; and we deſire to know what tenſion it ſuſtains. Of this we have a familiar example in a common roof. Let the two rafters AC, AD (fig. 12.), preſs on the tie-beam DC. We may ſuppoſe the whole weight to preſs vertically on the ridge A, as if a weight B were hung on there. We may repreſent this weight by the portion $\mathrm{A}b$ of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing bf and bg parallel to AD and AC, $\mathrm{A}g$ and $\mathrm{A}f$ will repreſent the preſſures on AC and AD. Produce AC till CH be equal to $\mathrm{A}f$. The point C is forced out in this direction, and with a force repreſented by this line. As this force is not perpendicularly acroſs the beam, it evidently ſtretches it; and this extending force muſt be withſtood by an equal force pulling it in the oppoſite direction. This muſt ariſe from a ſimilar oblique thruſt of the oppoſite rafter on the other end D. We concern ourſelves only with this extenſion at preſent; but we ſee that the coheſion of the beam does nothing but ſupply the balance to the extending forces. It muſt ſtill be ſupported externally, that it *may reſiſt*, and, by reſiſting obliquely, be ſtretched. The points C and D are ſupported on the walls, which they preſs in the directions CK and DO, parallel to $\mathrm{A}b$. If we draw HK parallel to DC, and HI parallel to CK (that is, to $\mathrm{A}b$), meeting DC produced in I, it follows from the compoſition of forces, that the point C would be ſupported by the two forces KC and IC. In like manner, making $\mathrm{DN} = \mathrm{A}g$, and completing the parallelogram DMNO, the point D would be ſupported by the forces OD and MD. If we draw go and fk parallel to DC, it is plain that they are equal to NO and CK, while $\mathrm{A}o$ and $\mathrm{A}k$ are equal to DO and CK, and $\mathrm{A}b$ is equal to the ſum of DO and CK (becauſe it is equal to $\mathrm{A}o + \mathrm{A}k$). The weight of the roof is equal to its vertical preſſure on the walls.

Thus we ſee, that while a preſſure on A, in the direction $\mathrm{A}b$, produces the ſtrains $\mathrm{A}f$ and $\mathrm{A}g$, on the pieces AC and AD, it alſo excites a ſtrain CI or DM in the piece DC. And this completes the mechaniſm of a frame; for all derive their efficacy from the triangles of which they are compoſed, as will appear more clearly as we proceed.

14 External action of a frame.

But there is more to be learned from this. The conſideration of the ſtrains on the two pieces AD and AC, by the action of a force at A, only ſhewed them as the means of propagating the ſame ſtrains in their own direction to the points of ſupport. But, by adding the ſtrains exerted in DC, we ſee that the frame becomes an intermedium, by which exertions may be made on other bodies, in certain directions and proportions; ſo that this frame may become part of a more complicated one, and, as it were, an element of its conſtitution. It is worth while to aſcertain the proportion of the preſſures CK and DO, which are thus exerted on the walls. The ſimilarity of triangles gives the following analogies:

$$\mathrm{DO} : \mathrm{DM} = \mathrm{A}b : b\mathrm{D}$$

$$\mathrm{CI}, \text{ or } \mathrm{DM} : \mathrm{CK} = \mathrm{C}b : \mathrm{A}b$$

$$\text{Therefore } \mathrm{DO} : \mathrm{CK} = \mathrm{C}b : b\mathrm{D}.$$

Or, *the preſſures on the points* C *and* D, *in the direction of the ſtraining force* A *b*, *are reciprocally proportional to the portions of* DC *intercepted by* A *b*.

Alſo, ſince $\mathrm{A}b$ is $= \mathrm{DO} + \mathrm{CK}$, we have

$$\mathrm{A}b : \mathrm{CK} = \mathrm{C}b + b\mathrm{D} \text{ (or CD)} : b\mathrm{D}, \text{ and}$$

$$\mathrm{A}b : \mathrm{DO} = \mathrm{CD} : b\mathrm{C}.$$

In general, any two of the three parallel forces $\mathrm{A}b$, DO, CK, are to each other in the reciprocal proportion of the parts of CD, intercepted between their directions and the direction of the third.

And this explains a ſtill more important office of the frame ADC. If one of the points, ſuch as D, be ſupported, an external power acting at A, in the direction $\mathrm{A}b$, and with an intenſity which may be meaſured by $\mathrm{A}b$, may be ſet in equilibrio, with another acting at C, in the direction CL, oppoſite to CK or $\mathrm{A}b$, and with an intenſity repreſented by CK: for ſince the preſſure CH is partly withſtood by the force IC, or the firmneſs of the beam DC ſupported at D, the force KC will complete the balance. When we do not attend to the ſupport at D, we conceive the force A *b* to be balanced by KC, or KC to be balanced by A *b*. And, in like manner, we may neglect the ſupport or force acting at A, and conſider the force DO as balanced by CK.

15
It becomes a lever.

Thus our frame becomes a lever, and we are able to trace the interior mechanical procedure which gives it its efficacy: it is by the intervention of the forces of coheſion, which connect the points to which the external forces are applied with the ſupported point or fulcrum, and with each other.

Theſe ſtrains or preſſures A *b*, DO, and CK, not being in the directions of the beams, may be called *tranſverſe*. We ſee that by their means a frame of carpentry may be conſidered as a ſolid body: but the example which brought this to our view is too limited for explaining the efficacy which may be given to ſuch conſtructions. We ſhall therefore give a general propoſition, which will more diſtinctly explain the procedure of nature, and enable us to trace the ſtrains as they are propagated through all the parts of the moſt complicated framing, finally producing the exertion of its moſt diſtant points.

16
General propoſition.

We preſume that the reader is now pretty well habituated to the conception of the ſtrains as they are propagated along the lines joining the points of a frame, and we ſhall therefore employ a very ſimple figure.

Let the ſtrong lines ACBD (fig. 13.) repreſent a frame of carpentry. Suppoſe that it is pulled at the point A by a force acting in the direction AE, but that it reſts on a fixed point C, and that the other extreme point B is held back by a power which reſiſts in the direction BF: It is required to determine the proportion of the ſtrains excited in its different parts, the proportion of the external preſſures at A and B, and the preſſure which is produced on the obſtacle or fulcrum C?

It is evident that each of the external forces at A and B tend one way, or to one ſide of the frame, and that each would cauſe it to turn round C if the other did not prevent it; and that if, notwithſtanding their action, it is turned neither way, the forces in actual exertion are in equilibrio by the intervention of the frame. It is no leſs evident that theſe forces concur in preſſing the frame on the prop C. Therefore, if the piece CD were away, and if the joints C and D be perfectly flexible, the pieces CA, CB would be turned round the prop C, and the pieces AD, DB would alſo turn with them, and the whole frame change its form. This ſhews, by the way, and we deſire it to be carefully kept in mind, that the firmneſs or ſtiffneſs of framing depends entirely on the triangles bounded by beams which are contained in it. An open quadrilateral may always change its ſhape, the ſides revolving round the angles. A quadrilateral may have an infinity of forms, without any change of its ſides, by merely puſhing two oppoſite angles towards each other, or drawing them aſunder. But when the three ſides of a triangle are determined, its ſhape is alſo invariably determined; and if two angles be held faſt, the third cannot be moved. It is thus that, by inſerting the bar CD, the figure becomes unchangeable; and any attempt to change it by applying a force to an angle A, immediately excites forces of attraction or repulſion between the particles of the ſtuff which form its ſides. Thus it happens, in the preſent inſtance, that a change of ſhape is prevented by the bar CD. The power at A preſſes its end againſt the prop; and in doing this it puts the bar AD on the ſtretch, and alſo the bar DB. Their places might therefore be ſupplied by cords or metal wires. Hence it is evident that DC is compreſſed, as is alſo AC: and, for the ſame reaſon, CB is alſo in a ſtate of compreſſion; for either A or B may be conſidered as the point that is impelled or withheld. Therefore DA and DB are ſtretched, and are reſiſting with attractive forces. DC and CB are compreſſed, and are reſiſting with repulſive forces. DB is alſo acting with repulſive forces, being compreſſed in like manner: and thus the ſupport of the prop, combined with the firmneſs of DC, puts the frame ADBC into the condition of the two frames in fig. 8. and fig. 9. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction AD, and a repulſive force acting in the direction AK. And ſince all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction DA. The condition of the point B is ſimilar to that of A, and D is alſo drawn in the direction DB. Thus the point D, being urged by the forces in the directions DA and DB, preſſes the beam DC on the prop, and the prop reſiſts in the oppoſite direction. Therefore the line DC is the diagonal of the parallelogram, whoſe ſides have the proportion of the forces which connect D with A and B. This is the principle on which the reſt of our inveſtigation proceeds. We may take DC as the repreſentation and meaſure of their joint effect. Therefore draw CH, CG, parallel to DA, DB. Draw HL, GO, parallel to CA, CB, cutting AE, BF in L and O, and cutting DA, DB in I and M. Complete the parallelograms ILKA, MONB. Then DG and AI are the equal and oppoſite forces which connect A and D; for GD = CH, = AI. In like manner DH and BM are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces, connecting A with D and with C. AI is one of them: Therefore AK is the other; and AL is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and oppoſite to AL. In like manner, the external force at B is equal and oppoſite to BO; and AL is to BO as the external force at A to the external force at B. The prop C reſiſts with forces equal to thoſe which are propagated to it from the points D, A, and C. Therefore it reſiſts with forces CH, CG, equal and oppoſite to DG, DH; and it reſiſts the compreſſions KA, NB, with equal and oppoſite forces C *k*, C *n*. Draw *k l*, *n o* parallel to AD, BD, and draw C *l* Q, C *o* P: It is plain that *k*CH*l* is a parallelogram equal to KAIL, and that C *l* is equal to AL. In like manner C *o* is equal to BO. Now the forces C *k*, CH, exerted by the prop, compoſe the force C *l*; and C *n*, CG compoſe the force C *o*. Theſe two forces C *l*, C *o* are equal and parallel to AL and BO; and therefore they are equal and oppoſite to the external forces acting at A and B. But they are (primitively) equal and oppoſite to the preſſures (or at leaſt the compounds of the preſſures) exerted on the prop, by the forces propagated to C from A, D, and B. Therefore the preſſures exerted on the prop are the ſame as if the external forces were applied there in the ſame directions as they are applied to A and B. Now if we make CV, CZ equal to C *l* and C *o*, and complete the parallelogram CVYZ; it is plain that the force YC is in equilibrio with *l* C and *o* C. Therefore the preſſures at A, C, and B, are ſuch as would balance if applied to one point.

Laſtly, in order to determine their proportions, draw CS and CR perpendicular to DA and DB. Alſo draw A *d*, B *f* perpendicular to CQ and CP; and draw C *g*, C *i* perpendicular to AE, BF.

The triangles CPR and BP*f* are ſimilar, having a common angle P, and a right angle at R and *f*.

In like manner the triangles CQS and A Q *d* are ſimilar. Alſo the triangles CHR, CGS are ſimilar, by reaſon of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

$$\begin{array}{ll} \mathrm{C}o : \mathrm{CP} = \mathrm{O}n : \mathrm{PB}, = & \mathrm{CG} : \mathrm{PB} \\ \mathrm{CP} : \mathrm{CR} = & \mathrm{PB} : f\mathrm{B} \\ \mathrm{CR} : \mathrm{CS} = & \mathrm{CH} : \mathrm{CG} \\ \mathrm{CS} : \mathrm{CQ} = & \mathrm{A}d : \mathrm{AQ} \\ \mathrm{CQ} : \mathrm{C}l = \mathrm{AQ} : \mathrm{K}l, = & \mathrm{AQ} : \mathrm{CH}. \end{array}$$

Therefore, by equality,

$$\begin{array}{ll} \mathrm{C}o : \mathrm{C}l = & \mathrm{A}d : f\mathrm{B} \\ \text{or } \mathrm{BO} : \mathrm{AL} = & \mathrm{C}g : \mathrm{C}i. \end{array}$$

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction (A).

17 Extenſive conſequences.

This propoſition (ſufficiently general for our purpoſe) is ſertile in conſequences, and furniſhes many uſeful inſtructions to the artiſt. The ſtrains LA, OB, CY, that are excited, occur in many, we may ſay in all, framings of carpentry, whether for edifices or engines, and are the ſources of their efficacy. It is alſo evident, that the doctrine of the tranſverſe ſtrength of timber is contained in this propoſition; for every piece of timber may be conſidered as an aſſemblage of parts, connected by forces which act in the direction of the lines which join the ſtrained points on the matter which lies between thoſe points, and alſo act on the reſt of the matter, exciting thoſe lateral forces which produce the inflexibility of the whole. See *Strength of Materials*, Encycl.

Thus it appears that this propoſition contains the principles which direct the artiſt to frame the moſt powerful levers; to ſecure uprights by ſhores or braces, or by ties and ropes; to ſecure ſcaffoldings for the erection of ſpires, and many other moſt delicate problems of his art. He alſo learns, from this propoſition, how to aſcertain the ſtrains that are produced, without his intention, by pieces which he intended for other offices, and which, by their tranſverſe action, put his work in hazard. In ſhort, this propoſition is the key to the ſcience of his art.

We would now counſel the artiſt, after he has made the tracing of the ſtrains and thruſts through the various parts of a frame familiar to his mind, and even amuſed himſelf with ſome complicated fancy framings, to read over with care the articles *Strength of Materials* and Roof in the *Encyclopædia*. He will now conceive its doctrines much more clearly than when he was conſidering them as abſtract theories. The mutual action of the woody fibres will now be eaſily comprehended, and his confidence in the reſults will be greatly increaſed.

18 Deciſion of a diſputed and very important queſtion.

There is a propoſition (n° 19. in the article Roof) which has been called in queſtion by ſeveral very intelligent perſons; and they ſay that Belidor has demonſtrated, in his Science des Ingenieurs, that a beam firmly fixed at both ends is not twice as ſtrong as when ſimply lying on the props, and that its ſtrength is increaſed only in the proportion of 2 to 3; and they ſupport this determination by a liſt of experiments recited by Belidor, which agree *preciſely* with it. Belidor alſo ſays, that Pitot had the ſame reſult in his experiments. Theſe are reſpectable authorities: but Belidor's reaſoning is any thing but demonſtration; and his experiments are deſcribed in ſuch an imperfect manner, that we cannot build much on them. It is not ſaid in what manner the battens were ſecured at the ends, any farther than that it was by *chevalets*. If by this word is meant a treſsle, we cannot conceive how they were employed; but we ſee it ſometimes uſed for a wedge or key. If the battens were wedged in the holes, their reſiſtance to fracture may be made what we pleaſe: they may be looſe, and therefore reſiſt little more than when ſimply laid on the props. They may be (and probably were) wedged very faſt, and bruiſed or crippled.

Our propoſition mentioned diſtinctly the ſecurity given to the ends of the beams. They were mortiſed into remote poſts. Our *preciſe* meaning was, that they were ſimply kept from riſing by theſe mortiſes, but at full liberty to bend up between E and I, and between G and K. Our aſſertion was not made from theory alone

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(A) The learned reader will perceive, that this analogy is preciſely the ſame with that of forces which are in equilibrio by the intervention of a lever. In fact, this whole frame of carpentry is nothing elſe than a *built* or *framed lever* in equilibrio. It is acting in the ſame manner as a ſolid, which occupies the whole figure compreſſed in the frame, or as a body of any ſize and ſhape whatever that will admit the three points of application A, C, and B. It is always in equilibrio in the caſe firſt ſtated; becauſe the preſſure *produced* at B by a force applied to A is always ſuch as balances it. The reader may alſo perceive, in this propoſition, the analyſis or tracing of thoſe internal mechanical forces which are indiſpenſably requiſite for the functions of a lever. The mechanicians have been extremely puzzled to find a legitimate demonſtration of the equilibrium of a lever ever ſince the days of Archimedes. Mr Vince has the honour of firſt demonſtrating, moſt ingeniouſly, the principle aſſumed by Archimedes, but without ſufficient ground for *his* demonſtration: but Mr Vince's demonſtration is only a putting the mind into that perplexed ſtate which makes it acknowledge the propoſition, but without a clear perception of its truth. The difficulty has proceeded from the abſtract notion of a lever, conceiving it as a mathematical line—inflexible, without reflecting how it is inflexible—for the very ſource of this indiſpenſable quality furniſhes the mechanical connection between the remote preſſures and the fulcrum; and this ſupplies the demonſtration (without the leaſt difficulty) of the deſperate caſe of a ſtraight lever urged by parallel forces. See Rotation, n° 11. *Encycl.*

alone (although we think the reaſoning incontrovertible), but was agreeable to numerous experiments made in thoſe preciſe circumſtances. Had we mortiſed the beams firmly into two very ſtout poſts, which could not be drawn nearer to each other by bending, the beam would have borne a *much* greater weight, as we have verified by experiment. We hope that the following mode of conceiving this caſe will remove all doubts.

Let LM be a long beam (fig. 14.) divided into ſix equal parts, in the points D, B, A, C, E. Let it be firmly ſupported at L, B, C, M. Let it be cut thro' at A, and have compaſs joints at B and C. Let FB, GC be two equal uprights, reſting on B and C, but without any connection. Let AH be a ſimilar and equal piece, to be occaſionally applied at the ſeam A. Now let a thread or wire AGE be extended over the piece GC, and made faſt at A, G, and E. Let the ſame thing be done on the other ſide of A. If a weight be now laid on at A, the wires AFD, AGE will be ſtrained, and may be broken. In the inſtant of fracture we may ſuppoſe their ſtrains to be repreſented by A *f* and A *g*. Complete the parallelogram, and A *a* is the magnitude of the weight. It is plain that nothing is concerned here but the coheſion of the wires; for the beam is ſawed through at A, and its parts are perfectly moveable round B and C.

Inſtead of this proceſs apply the piece AH below A, and keep it there by ſtraining the ſame wire BHC over it. Now lay on a weight. It muſt preſs down the ends of BA and CA, and cauſe the piece AH to ſtrain the wire BHC. In the inſtant of fracture of *the ſame* wire, its reſiſtances H *b* and H *c* muſt be equal to A *f* and A *g*, and the weight *h* H which breaks them muſt be equal to A *a*.

Laſtly employ all the three pieces FB, AH, GC, with the ſame wire attached as before. There can be no doubt but that the weight which breaks all the four wires muſt be $= a\,A + h\,H$, or twice A *a*.

The reader cannot but ſee that the wires perform the very ſame office with the fibres of an entire beam LM held faſt in the four holes D, B, C, and E, of ſome upright poſts.

In the experiments for verifying this, by breaking ſlender bars of fine deal, we get complete demonſtration, by meaſuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam ſimply laid on the props B and C: and there are many curious inferences to be made from theſe obſervations, but we have not room for them in this place.

19
The beſt manner of framing purlins.

We may obſerve, by the way, that we learn from this caſe, that purlins are able to carry twice the load when notched into the rafters that they carry when mortiſed into them, which is the moſt uſual manner of framing them. So would the binding joiſts of floors; but this would double the thickneſs of the flooring. But this method ſhould be followed in every poſſible caſe, ſuch as breaſt ſummers, lintels over ſeveral pillars, &c. Theſe ſhould never be cut off and mortiſed into the ſides of every upright; numberleſs caſes will occur which ſhew the importance of the maxim.

We muſt here remark, that the proportion of the ſpaces BC and CM, or BC and LB, has a very ſenſible effect on the ſtrength of the beam BC; but we have not yet ſatisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the ſerpentine form of the curve of the beam before fracture. This ſhould be attended to in the conſtruction of the ſprings of carriages. Theſe are frequently ſupported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the eaſieſt motion to the body of the carriage. We alſo think that it is connected with that deviation from the beſt theory obſervable in Buffon's experiments on various lengths of the ſame ſcantling. The force of the beams diminiſhed much more than in the inverſe proportion of their lengths.

20
Ties are in general better than ſtruts.

We have ſeen that it depends entirely on the poſition of the pieces in reſpect of their points of ultimate ſupport, and of the direction of the external force which produces the ſtrains, whether any particular piece is in a ſtate of extenſion or of compreſſion. The knowledge of this circumſtance may greatly influence us in the choice of the conſtruction. In many caſes we may ſubſtitute ſlender iron rods for maſſive beams, when the piece is to act the part of a tie. But we muſt not invert this diſpoſition; for when a piece of timber acts as a ſtrut, and is in a ſtate of compreſſion, it is next to certain that it is not equally compreſſible in its oppoſite ſides through the whole length of the piece, and that the compreſſing force on the abutting joint is not acting in the moſt equable manner all over the joint. A very trifling inequality in either of theſe circumſtances (eſpecially in the firſt) will compreſs the beam more on one ſide than on the other. This cannot be without the beam's bending, and becoming concave on that ſide on which it is moſt compreſſed. When this happens, the frame is in danger of being cruſhed, and ſoon going to ruin. It is therefore indiſpenſably neceſſary to make uſe of beams in all caſes where ſtruts are required of conſiderable length, rather than of metal rods of ſlender dimenſions, unleſs in ſituations where we can effectually prevent their bending, as in truſſing a girder internally, where a caſt iron ſtrut may be firmly caſed in it, ſo as not to bend in the ſmalleſt degree. In caſes where the preſſures are enormous, as in the very oblique ſtruts of a centre or arch frame, we muſt be particularly cautious to do nothing which can facilitate the compreſſion of either ſide. No mortiſes ſhould be cut near to one ſide; no lateral preſſures, even the ſlighteſt, ſhould be allowed to touch it. We have ſeen a pillar of fir 12 inches long and one inch in ſection, when loaded with three tons, ſnap in an inſtant when preſſed on one ſide by 16 pounds, while another bore $4\frac{1}{2}$ tons without hurt, becauſe it was incloſed (looſely) in a ſtout pipe of iron.

In ſuch caſes of enormous compreſſion, it is of great importance that the compreſſing force bear equally on the whole abutting ſurface. The German carpenters are accuſtomed to put a plate of lead over the joint. This prevents, in ſome meaſure, the penetration of the end fibres. Mr Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the ſtrut. By this contrivance the unavoidable change of form of the triangle made no partial bearing of either angle of the abutment. This always has a tendency to ſplinter off the heel of the beam where it preſſes ſtrongeſt. It is a very judicious practice.

When circumſtances allow it, we ſhould rather em-

ploy

CARPENTRY. PLATE IX.

Fig. 9.

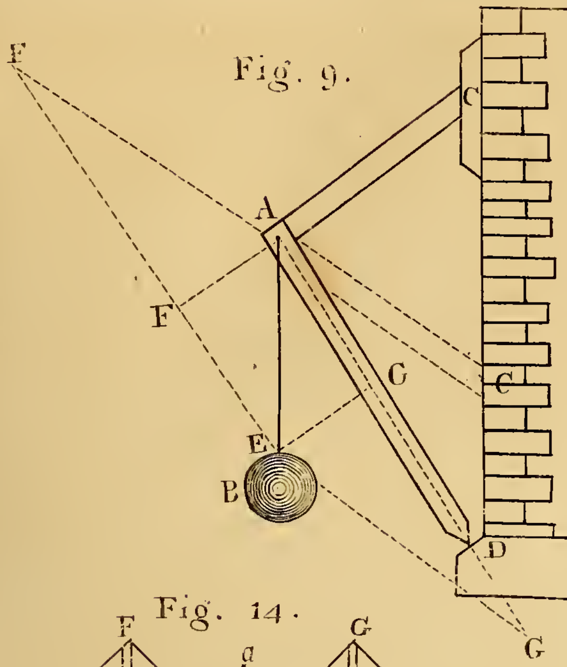


Fig. 10.

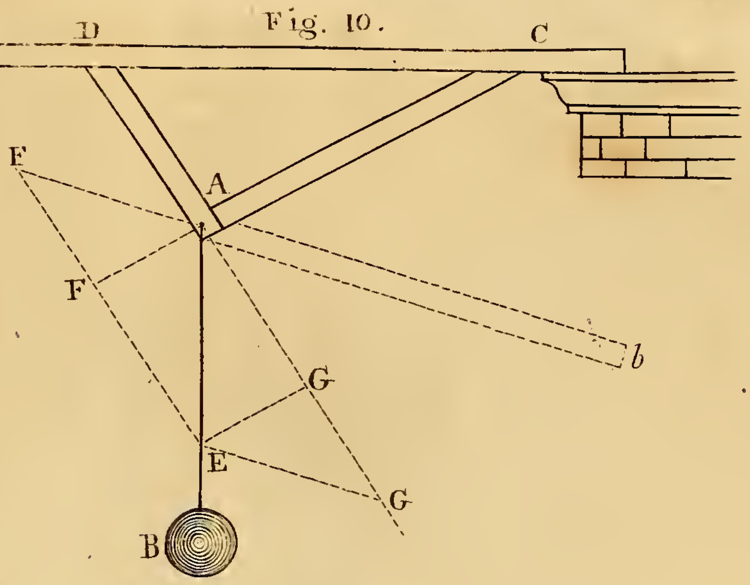


Fig. 14.

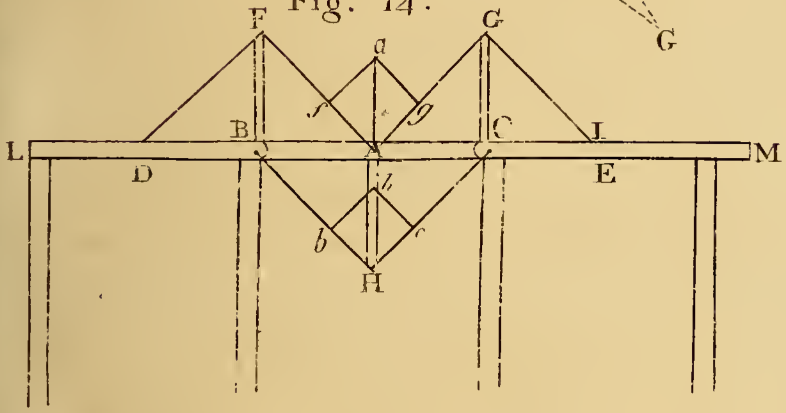


Fig. 15.

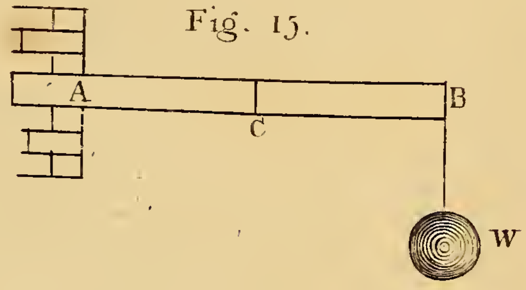


Fig. 11.

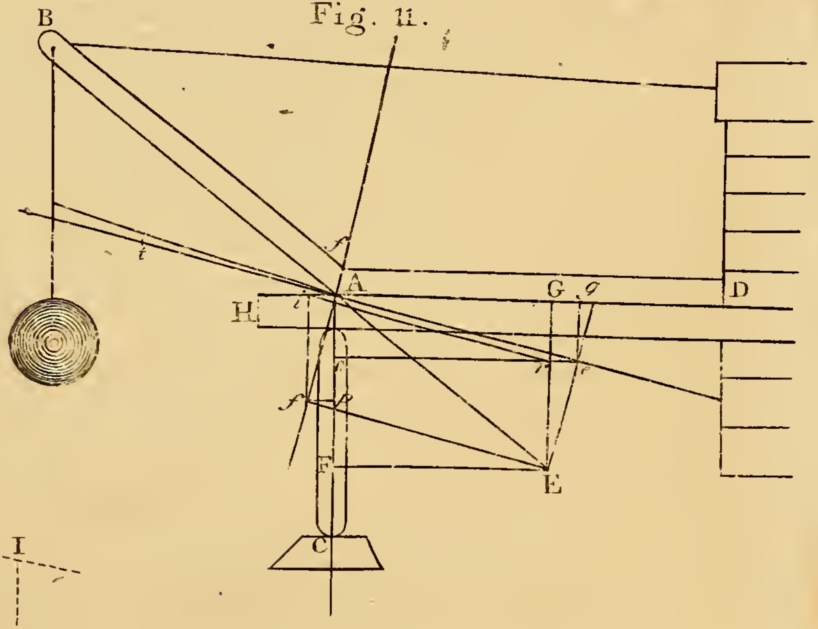


Fig. 12.

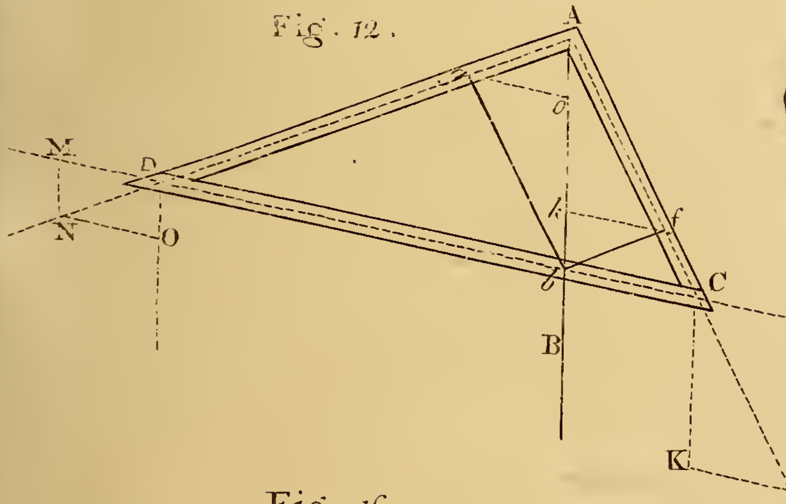


Fig. 16.

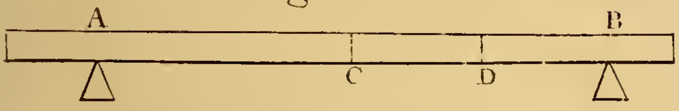
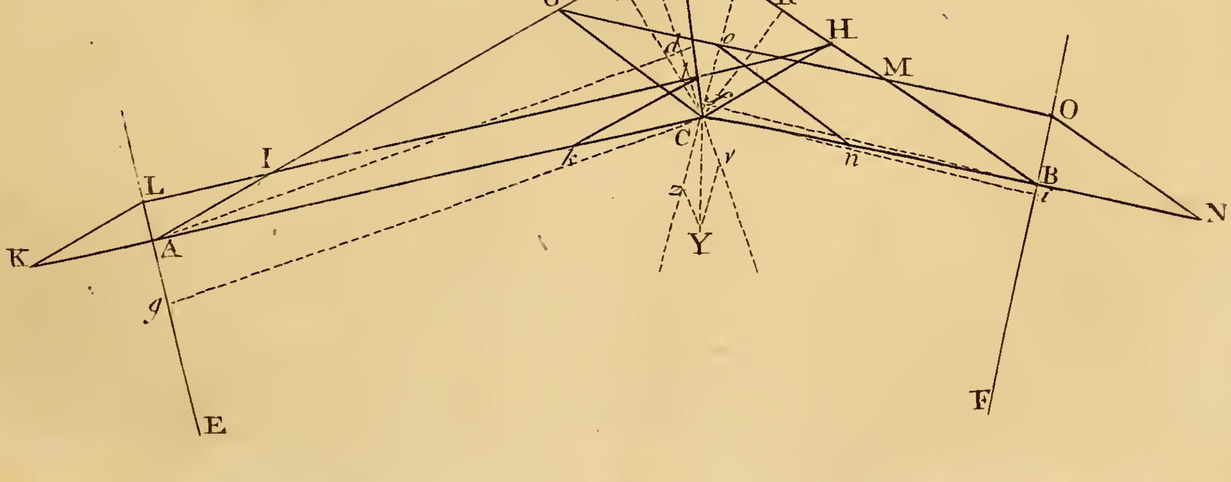


Fig. 13.



Bowes Sc.

ploy ties than ſtruts for ſecuring a beam againſt lateral ſtrains. When an upright pillar, ſuch as a flag ſtaff, a maſt, or the uprights of a very tall ſcaffolding, are to be ſhoared up, the dependence is more certain on thoſe braces that are ſtretched by the ſtrain than on thoſe which are compreſſed. The ſcaffolding of the iron bridge near Sunderland had ſome ties very judiciouſly diſpoſed, and others with leſs judgment.

We ſhould proceed to conſider the tranſverſe ſtrains as they affect the various parts of a frame of carpentry; but we have very little to add to what has been ſaid already in the article *Strength of Materials* (Encycl.) and in the article Roof. What we ſhall add in this article will find a place in our occaſional remarks on different works. It may, however, be of uſe to recal to the reader's memory the following propoſitions.

21 General heorems oncerning he relative trength of eams.

1. When a beam AB (fig. 15.) is firmly fixed at the end A, and a ſtraining force acts perpendicularly to its length at any point B, the ſtrain occaſioned at any ſection C between B and A is proportional to CB, and may therefore be repreſented by the product $W + CB$; that is, by the product of the number of tons, pounds, &c. which meaſure the ſtraining force, and the number of feet, inches, &c. contained in CB. As the loads on a beam are eaſily conceived, we ſhall ſubſtitute this for any other ſtraining force.

2. If the ſtrain or load is uniformly diſtributed along any part of the beam lying beyond C (that is, further from A), the ſtrain at C is the ſame as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

3. The ſtrain on any ſection D of a beam AB (fig 16.) reſting freely on two props A and B, is $w \times \frac{AD \times DB}{AB}$ (ſee Roof, nº 19. and *Strength of Materials*, nº 92, &c. *Encycl.*). Therefore,

4. The ſtrain on the middle point, by a force applied there, is one-fourth of the ſtrain which the ſame force would produce, if applied to one end of a beam of the ſame length, having the other end fixed.

5. The ſtrain on any ſection C of a beam, reſting on two props A and B, occaſioned by a force applied perpendicularly to another point D, is proportional to the rectangle of the exterior ſegments, or is equal to $w \times \frac{AC \times DB}{AB}$. Therefore

The ſtrain at C occaſioned by the preſſure on D, is the ſame with the ſtrain at D occaſioned by the ſame preſſure on C.

6. The ſtrain on any ſection D, occaſioned by a load uniformly diffuſed over any part EF, is the ſame as if the two parts ED, DF of the load were collected at their middle points *e* and *f*. Therefore

The ſtrain on any part D, occaſioned by a load uniformly diſtributed over the whole beam, is one-half of the ſtrain that is produced when the ſame load is laid on at D; and

The ſtrain on the middle point C, occaſioned by a load uniformly diſtributed over the whole beam, is the ſame which half that load would produce if laid on at C.

7. A beam ſupported at both ends on two props B and C (fig. 14), will carry twice as much when the ends beyond the props are kept from riſing, as it will carry when it reſts looſely on the props.

8. Laſtly, the tranſverſe ſtrain on any ſection, occaſioned by a force applied obliquely, is diminiſhed in the proportion of the ſine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the ſtrain is one-half of the ſtrain occaſioned by the ſame force acting perpendicularly.

On the other hand, the RELATIVE STRENGTH of a beam, or its power in any particular ſection to reſiſt any tranſverſe ſtrain, is proportional to the abſolute coheſion of the ſection directly, to the diſtance of its centre of effort from the axis of fracture directly, and to the diſtance from the ſtrained point inverſely.

Thus in a rectangular ſection of the beam, of which b is the breadth, d the depth (that is, the dimenſion in the direction of the ſtraining force), meaſured in inches, and f the number of pounds which one ſquare inch will juſt ſupport without being torn aſunder, we muſt have $f \times b \times d^2$, proportional to $w \times CB$ (fig. 15.) Or, $f \times b \times d^2$, multiplied by ſome number m, depending on the nature of the timber, muſt be equal to $w \times CB$. Or, in the caſe of the ſection C of fig. 16. that is ſtrained by the force w applied at D, we muſt have $m \times f b d^2 = w \times \frac{AC \times DB}{AB}$. Thus if the beam is of ſound oak, m is very nearly $= \frac{1}{9}$ (ſee *Strength of Materials*, nº 116, Encycl.). Therefore we have $\frac{f b d^2}{9} = w \times \frac{AC \times CB}{AB}$.

Hence we can tell the preciſe force w which any ſection C can juſt reſiſt when that force is applied in any way whatever. For the above mentioned formula gives $w = \frac{f b d^2}{9CB}$, for the caſe repreſented by fig. 15. But the caſe repreſented in fig. 16. having the ſtraining force applied at D, gives the ſtrain at C $(= w) = f \times \frac{b d^2 \times AB}{9AC \times CB}$.

Example. Let an oak beam, four inches ſquare, reſt freely on the props A and B, ſeven feet apart, or 84 inches. What weight will it juſt ſupport at its middle point C, on the ſuppoſition that a ſquare inch rod will juſt carry 16,000 pounds, pulling it aſunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 42}$, or $w = \frac{86016000}{15876}$, $= 5418$ pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the ſtraining force acted on a point D, half way between C and B, the force ſufficient to break the beam at C would be $= \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} = 10836$ lbs.

Had the beam been ſound red fir, we muſt have taken $f = 10,000$ nearly, and m nearly 8; for although fir be leſs coheſive than oak in the proportion of 5 to 8 nearly, it is leſs compreſſible, and its axis of fracture is therefore nearer to the concave ſide.

22 Of joints.

Having conſidered at ſufficient length the ſtrains of to attend to the ſhrinking of the timbers by drying. When two timbers abut obliquely, the joint ſhould be moſt full at the obtuſe angle of the end; becauſe, by drying that angle grows more obtuſe, and the beam would then be in danger of ſplintering off at the acute angle.

26
We muſt not wedge oo hard.

It is evident, that the niceſt work is indiſpenſably neceſſary in building up a beam. The parts muſt abut on each other completely, and the ſmalleſt play or void takes away the whole efficacy. It is uſual to give the butting joints a ſmall taper to one ſide of the beam, ſo that they may require moderate blows of a maul to force them in, and the joints may be perfectly cloſe when the external ſurfaces are even on each ſide of the beam. But we muſt not exceed in the leaſt degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a ſtate of violent ſtrain, and the abutments are perhaps ready to ſplinter off by a ſmall addition of preſſure. This is like too ſevere a proof for artillery; which, though not ſufficient to burſt the pieces, has weakened them to ſuch a degree, that the ſtrain of ordinary ſervice is ſufficient to complete the fracture. The *workman* is tempted to exceed in this, becauſe it ſmooths off and conceals all uneven ſeams; but he muſt be watched. It is not unuſual to leave ſome abutments open enough to admit a thin wedge reaching through the beam. Nor is this a bad practice, if the wedge is of materials which is not compreſſed by the driving or the ſtrain of ſervice. Iron would be preferable for this purpoſe, and for the joggles, were it not that by its too great hardneſs it cripples the fibres of timber to ſome diſtance. In conſequence of this, it often happens that, in beams which are ſubjected to deſultory and ſudden ſtrains (as in the levers of reciprocating engines), the joggles or wedges widen the holes, and work themſelves looſe: Therefore ſkilful engineers never admit them, and indeed as few bolts as poſſible, for the ſame reaſon: but when reſiſting a ſteady or dead pull, they are not ſo improper, and are frequently uſed.

27
Building of maſts.

Beams are built up, not only to increaſe their dimenſions in the direction of the ſtrain (which we have hitherto called their depth), but alſo to increaſe their breadth or the dimenſions perpendicular to the ſtrain. We ſometimes double the breadth of a girder which is thought too weak for its load, and where we muſt not increaſe the thickneſs of the flooring. The maſt of a great ſhip of war muſt be made bigger athwartſhip, as well as fore and aft. This is one of the niceſt problems of the art; and profeſſional men are by no means agreed in their opinions about it. We do not preſume to decide; and ſhall content ourſelves with exhibiting the different methods.

28
Method uſed in the French Navy.

The moſt obvious and natural method is that ſhewn in fig. 20. It is plain that (independent of the connection of croſs bolts, which are uſed in them all when the beams are ſquare) the piece C cannot bend in the direction of the plane of the figure without bending the piece D along with it. This method is much uſed in the French navy; but it is undoubtedly imperfect. Hardly any two great trees are of equal quality, and ſwell or ſhrink alike. If C ſhrinks more than D, the feather of C becomes looſe in the groove wrought in D to receive it; and when the beam bends, the parts can ſlide on each other like the plates of a coach ſpring; and if the bending is in the direction *e f*, there is nothing to hinder this ſliding but the bolts, which ſoon work themſelves looſe in the bolt-holes.

29
Another method.

Fig. 21. exhibits another method. The two halves of the beam are tabled into each other in the ſame manner as in fig. 17. It is plain that this will not be affected by the unequal ſwelling or ſhrinking, becauſe this is inſenſible in the direction of the fibres; but when bent in the direction *a b*, the beam is weaker than fig. 20. bent in the direction *e f*. Each half of fig. 20. has, in every part of its length, a thickneſs greater than half the thickneſs of the beam. It is the contrary in the alternate portions of the halves of fig. 21. When one of them is bent in the direction AB, it is plain that it drags the other with it by means of the croſs butments of its tables, and there can be no longitudinal ſliding. But unleſs the work is accurately executed, and each hollow completely filled up by the table of the other piece, there will be a lateral ſlide along the croſs joints ſufficient to compenſate for the curvature: and this will hinder the one from compreſſing or ſtretching the other in conformity to this curvature.

30
Its imperfection.

The imperfection of this method is ſo obvious, that it has ſeldom been practiſed; but it has been combined with the other, as is repreſented in fig. 22. where the beams are divided along the middle, and the tables in each half are alternate, and alternate alſo with the tables of the other half. Thus 1, 3, 4, are prominent, and 5, 2, 6, are depreſſed. This conſtruction evidently puts a ſtop to both ſlides, and obliges every part of both pieces to move together. *a b* and *c d* ſhow ſections of the built-up beam correſponding to AB and CD.

No more is intended in this practice by any intelligent artiſt, than the cauſing the two pieces to act together in all their parts, although the ſtrains may be unequally diſtributed on them. Thus, in a built-up girder, the binding joiſts are frequently mortiſed into very different parts of the two ſides. But many ſeem to aim at making the beam ſtronger than if it were of one piece; and this inconſiderate project has given riſe to many whimſical modes of tabling and ſcarfing, which we need not regard.

31
Britiſh method;

The practice in the Britiſh dock-yards is ſomewhat different from any of theſe methods. The pieces are tabled as in fig. 22. but the tables are not thin parallelopipeds, but thin priſms. The two outward joints or viſible ſeams are ſtraight lines, and the table n° 1. riſes gradually to its greateſt thickneſs in the axis. In like manner the hollow 5 for receiving the oppoſite table, ſinks gradually from the edge to its greateſt depth in the axis. Fig. 23. repreſents a ſection of a round piece of timber built up in this way, where the full line EFGH is the ſection correſponding to AB of fig. 22. and the dotted line EGFH is the ſection correſponding to CD.

This conſtruction, by making the external ſeam ſtraight, leaves no lodgment for water, and looks much fairer to the eye: but it appears to us that it does not give ſuch firm hold when the maſt is bent in the direction EH. The exterior parts are moſt ſtretched and moſt compreſſed by this bending; but there is hardly any abutment in the exterior parts of theſe tables. In the very axis, where the abutment is the firmeſt, there is little or no difference of extenſion and compreſſion.

But this conſtruction has an advantage, which we imagine much more than compenſates for theſe imperfections, at leaſt in the particular caſe of a round maſt: it will draw together by hooping incomparably better than any of the others. If the cavity be made ſomewhat too ſhallow for the prominence of the tables, and if this be done uniformly along the whole length, it will make a ſomewhat open ſeam; and this opening can be regulated with the utmoſt exactneſs from end to end by the plane. The heart of thoſe vaſt trunks is very ſenſibly ſofter than the exterior circles: Therefore, when the whole is hooped, and the hoops hard driven, and at conſiderable intervals between each ſpell —we are confident that all may be compreſſed till the ſeam diſappears; and then the whole makes one piece, *much* ſtronger than if it were an original log of that ſize, becauſe the middle has become, by compreſſion, as ſolid as the cruſt, which was naturally firmer, and reſiſted farther compreſſion. We verified this beyond a doubt, by hooping a built ſtick of a timber which has this inequality of firmneſs in a remarkable degree, and it was nearly twice as ſtrong as another of the ſame ſize.

Our maſtmakers are not without their fancies and whims; and the manner in which our maſts and yards are generally built up, is not near ſo ſimple as fig. 22.: but it conſiſts of the ſame eſſential parts, acting in the very ſame manner, and derives all its efficacy from the principles which are here employed.

32 Attended with peculiar advantages.

This conſtruction is particularly ſuited to the ſituation and office of a ſhip's maſt. It has no bolts; or, at leaſt, none of any magnitude, or that make very important parts of its conſtruction. The moſt violent ſtrains perhaps that it is expoſed to, is that of twiſting, when the lower yards are cloſe braced up by the force of many men acting by a long lever. This form reſiſts a twiſt with peculiar energy: it is therefore an excellent method for building up a great ſhaft for a mill. The way in which they are uſually built up is by reducing a central log to a polygonal priſm, and then filling it up to the intended ſize by *planting* pieces of timber along its ſides, either ſpiking them down, or cocking them into it by a feather, or joggling them by ſlips of hard wood ſunk into the central log and into the ſlips. *N. B.* Joggles of elm are ſometimes uſed in the middle of the large tables of maſts; and when ſunk into the firm wood near the ſurface, they muſt contribute much to the ſtrength. But it is very neceſſary to employ wood not much harder than the pine; otherwiſe it will ſoon enlarge its bed, and become looſe; for the timber of theſe large trunks is very ſoft.

The moſt general reaſon for piecing a beam is to increaſe its length. This is frequently neceſſary, in order to procure tie-beams for very wide roofs. Two pieces muſt be ſcarfed together.—Numberleſs are the modes of doing this; and almoſt every maſter carpenter has his favorite noſtrum. Some of them are very ingenious: But here, as in other caſes, the moſt ſimple are

33 Various methods of ſcarfing.

commonly the ſtrongeſt. We do not imagine that any, the moſt ingenious, is equally ſtrong with a tie conſiſting of two pieces of the ſame ſcantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artleſs and clumſy tie-beam; but we only ſay that it will be ſtronger than any that is more artificially made up of the ſame thickneſs of timber. This, we imagine, will appear ſufficiently certain.

The ſimpleſt and moſt obvious ſcarfing (after the one now mentioned) is that repreſented in fig. 24. n° 1. and 2. If conſidered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the ſtrength of an entire piece, ſuppoſing that the bolts (which are the only connections) are faſt in their holes. N° 2. requires a bolt in the middle of the ſcarf to give it that ſtrength; and, in every other part, is weaker on one ſide or the other.

But the bolts are very apt to bend by the violent ſtrain, and require to be ſtrengthened by uniting their ends by iron plates; in which caſe it is no longer a wooden tie. The form of n° 1. is better adapted to the office of a pillar than n° 2.; eſpecially if its ends be formed in the manner ſhewn in the elevation n° 3. By the ſally given to the ends, the ſcarf reſiſts an effort to bend it in that direction. Beſides, the form of n° 2. is unſuitable for a poſt; becauſe the pieces, by ſliding on each other by the preſſure, are apt to ſplinter off the tongue which confines their extremity.

Fig. 25. and 26. exhibit the moſt approved form of a ſcarf, whether for a tie or for a poſt. The key repreſented in the middle is not eſſentially neceſſary; the two pieces might ſimply meet ſquare there. This form, without a key, needs no bolts (although they ſtrengthen it greatly); but, if worked very true and cloſe, and with ſquare abutments, will hold together, and will reſiſt bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightneſs. The ſame precaution muſt be obſerved that we mentioned on another occaſion, not to produce a conſtant internal ſtrain on the parts by overdriving the key. The form of fig. 25. is by far the beſt; becauſe the triangle of 26. is much eaſier ſplintered off by the ſtrain, or by the key, than the ſquare wood of 25. It is far preferable for a poſt, for the reaſon given when ſpeaking of fig. 24. n° 1. and n° 2. Both may be formed with a ſally at the ends equal to the breadth of the key. In this ſhape fig. 25. is vaſtly well ſuited for joining the parts of the long corner poſts of ſpires and other wooden towers. Fig. 25. n° 2. differs from n° 1. only by having three keys. The principle and the longitudinal ſtrength are the ſame. The long ſcarf of n° 2. tightened by the three keys, enables it to reſiſt a bending much better.

None of theſe ſcarfed tie-beams can have more than one-third of the ſtrength of an entire piece, unleſs with the aſſiſtance of iron plates; for if the key be made thinner than one-third, it has leſs than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the ſimple form of fig. 24. n° 1. is ſtronger than thoſe more ingenious ſcarfings. It may be ſtrengthened againſt lateral bending by a little tongue, or by a ſally; but it cannot have both.

The ſtrongeſt of all methods of piecing a tie-beam would be to ſet the parts end to end, and graſp them between other pieces on each ſide, as in fig. 27. This is what the ſhip-carpenter calls *fiſhing* a beam; and is a frequent practice for occaſional repairs. Mr Perronet uſed it for the tie-beams or ſtretchers, by which he connected

34 Fiſhing a beam.

nected the oppoſite feet of a centre, which was yielding to its load, and had puſhed aſide one of the piers above four inches. Six of theſe not only withſtood a ſtrain of 1800 tons, but, by wedging behind them, he brought the feet of the truſs 2½ inches nearer. The ſtretchers were 14 inches by 11 of ſound oak, and could have withſtood three times that ſtrain. Mr Perronet, fearing that the great length of the bolts employed to connect the beams of theſe ſtretchers would expoſe them to the riſk of bending, ſcarfed the two ſide pieces into the middle piece. The ſcarfing was of the triangular kind (*Trait de Jupiter*), and only an inch deep, each face being two feet long, and the bolt paſſed through cloſe to the angle.

In piecing the pump rods, and other wooden ſtretchers of great engines, no dependence is had on ſcarfing; and the engineer connects every thing by iron ſtraps. We doubt the propriety of this, at leaſt in caſes where the bulk of the wooden connection is not inconvenient. Theſe obſervations muſt ſuffice for the methods employed for connecting the parts of a beam; and we now proceed to conſider what are more uſually called the joints of a piece of carpentry.

35 Square joints. Where the beams ſtand ſquare with each other, and the ſtrains are alſo ſquare with the beams, and in the plane of the frame, the common mortiſe and tenon is the moſt perfect junction. A pin is generally put through both, in order to keep the pieces united, in oppoſition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, ſo that it ſhall draw the tenon tight into the mortiſe, and cauſe the ſhoulder to butt cloſe, and make neat work; and he knows the riſk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may juſt obſerve, that ſquare holes and pins are much preferable to round ones for this purpoſe, bringing more of the wood into action, with leſs tendency to ſplit it. The ſhip carpenters have an ingenious method of making long wooden bolts, which do not paſs completely through, take a very faſt hold, though not nicely fitted to their holes, which they muſt not be, leſt they ſhould be crippled in driving. 36 Foxtail wedging. They call it *foxtail wedging*. They ſtick into the point of the bolt a very thin wedge of hard wood, ſo as to project a proper diſtance: when this reaches the bottom of the hole by driving the bolt, it ſplits the end of it, and ſqueezes it hard to the ſide. This may be practiſed with advantage in carpentry. If the ends of the mortiſe are widened inwards, and a thin wedge be put into the end of the tenon, it will have the ſame effect, and make the joint equal to a dovetail. But this riſks the ſplitting the piece beyond the ſhoulder of the tenon, which would be unſightly. This may be avoided as follows: Let the tenon T, fig. 28. have two *very* thin wedges *a* and *c* ſtuck in near its angles, projecting equally: at a very ſmall diſtance within theſe, put in two ſhorter ones *b*, *d*, and more within theſe if neceſſary. In driving this tenon, the wedges *a* and *c* will take firſt, and ſplit off a thin ſlice, which will eaſily bend without breaking. The wedges *b*, *d*, will act next, and have a ſimilar effect, and the others in ſucceſſion. The thickneſs of all the wedges taken together muſt be equal to the enlargement of the mortiſe toward the bottom.

When the ſtrain is tranſverſe to the plane of the two beams, the principles laid down in nº 85, 86, of the article *Strength of Materials*, will direct the artiſt in placing his mortiſe. Thus the mortiſe in a girder for receiving the tenon of a binding joiſt of a floor ſhould be as near the upper ſide as poſſible, becauſe the girder becomes concave on that ſide by the ſtrain. But as this expoſes the tenon of the binding-joiſt to the riſk of being torn off, we are obliged to mortiſe farther down. The form (fig. 29.) generally given to this joint is extremely judicious. The ſloping part *a b* gives a very firm ſupport to the additional bearing *e d*, without much weakening of the girder. This form ſhould be copied in every caſe where the ſtrain has a ſimilar direction.

37 Oblique mortiſe and tenon. The joint that moſt of all demands the careful attention of the artiſt, is that which connects the ends of beams, one of which puſhes the other very obliquely, putting it into a ſtate of extenſion. The moſt familiar inſtance of this is the foot of a rafter preſſing on the tie-beam, and thereby *drawing* it away from the other wall. When the direction is very oblique (in which caſe the extending ſtrain is the greateſt), it is difficult to give the foot of the rafter ſuch a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a ſmall diſtance beyond the foot of the rafter: but, indeed, the dimenſions which are given to tie-beams, for other reaſons, are always ſufficient to give enough of abutment when judiciouſly employed. Unfortunately this joint is much expoſed to failure by the effects of the weather. It is much expoſed, and frequently periſhes by rot, or becomes ſo ſoft and friable that a very ſmall force is ſufficient, either for pulling the filaments out of the tie-beam, or for cruſhing them together. We are therefore obliged to ſecure it with particular attention, and to avail ourſelves of every circumſtance of conſtruction.

One is naturally diſpoſed to give the rafter a deep hold by a long tenon; but it has been frequently obſerved in old roofs that ſuch tenons break off. Frequently they are obſerved to tear up the wood that is above them, and puſh their way through the end of the tie-beam. This in all probability ariſes from the firſt ſagging of the roof, by the compreſſion of the rafters and of the head of the king poſt. The head of the rafter deſcends, the angle with the tie-beam is diminiſhed by the rafter revolving round its ſtep in the tie-beam. By this motion the heel or inner angle of the rafter becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very ſhort, and being ſtill freſh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortiſe, and then puſhes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a ſhape which abuts firmly, in the direction of the thruſt, on the ſolid bottom of the mortiſe, which is well ſupported on the under ſide by the wall plate. This form has the farther advantage of having no tendency to tear up the end of the mortiſe. This form is repreſented in fig. 30. The tenon has a ſmall portion *a b* cut perpendicular to the ſurface of the tie-beam, and the reſt *b c* is perpendicular to the rafter.

But if the tenon is not ſufficiently ſtrong (and it is

One of the old roof had 273, but had many inactive timbers, and others ill diſpoſed (*N. B.* The figure which we gave of it in the article Roof, copied from Price, is very erroneous). The internal truſs FCF is admirably contrived for ſupporting the exterior rafters, without any preſſure on the far projecting ends of the tie-beam. The former roof had bent them greatly, ſo as to appear ungraceful.

We think that the camber (ſix inches) of the tie-beam is rather hurtful; becauſe by ſettling, the beam lengthens; and this muſt be accompanied by a *conſiderable* ſinking of the roof. This will appear by calculation.

45 Birmingham theatre.

Fig. 40. the roof of Birmingham theatre, conſtructed by Mr Geo. Saunders. The ſpan is 80 feet clear, and the truſſes are 10 feet apart.

A, Is an oak corbel	9 × 5
B, Inner plate	9 × 9
C, Wall plate	8 × 5½
D, Pole plate	7 × 5
E, Beam	15 × 15
F, Straining beam	12 × 9
G, Oak king poſt (in the ſhaft)	9 × 9
H, Oak queen poſt (in the ſhaft)	7 × 9
I, Principal rafters	9 × 9
K, Common ditto	4 × 2½
L, Principal braces	9 and 6 × 9
M, Common ditto	6 × 9
N, Purlins	7 × 5
Q, Straining ſill	5½ × 9

This roof is a fine ſpecimen of Britiſh carpentry, and is one of the boldeſt and lighteſt roofs in Europe. The ſtraining ſill Q gives a firm abutment to the principal braces, and the ſpace between the poſts is 19½ feet wide, affording roomy workſhops for the carpenters and other workmen connected with a theatre. The contrivance for taking double hold of the wall, which is very thin, is excellent. There is alſo added a beam (marked R), bolted down to the tie-beams. The intention of this was to prevent the total failure of ſo bold a truſſing, if any of the tie-beams ſhould fail at the end by rot.

46 Drury Lane theatre.

Akin to this roof is fig. 41. the roof of Drury Lane theatre, 80 feet 3 inches in the clear, and the truſſes 15 feet apart, conſtructed by Mr Edward Grey Saunders.

A, Beams	10 by 7
B, Rafters	7 × 7
C, King poſts	12 × 7
D, Struts	5 × 7
E, Purlins	9 × 5
G, Pole plates	5 × 5
I, Common rafters	5 × 4
K, Tie-beam to the main truſs	15 × 12
L, Poſts to ditto	15 × 12
M, Principal braces to ditto	14 and 12 × 12
N, Struts	8 × 12
P, Straining beams	12 × 12

The main beams are truſſed in the middle ſpace with oak truſſes 5 inches ſquare. This was neceſſary for its width of 32 feet, occupied by the carpenters, painters, &c. The great ſpace between the truſſes afford good ſtore-rooms, dreſſing rooms, &c.

It is probable that this roof has not its equal in the world for lightneſs, ſtiffneſs, and ſtrength. The main truſs is ſo judiciouſly framed, that each of them will ſafely bear a load of near 300 tons; ſo it is not likely that they will ever be quarter loaded. The diviſion of the whole into three parts makes the exterior roofings very light. The ſtrains are admirably kept from the walls, and the walls are even firmly bound together by the roof. They alſo take off the dead weight from the main truſs one-third.

47 Remarks.

The intelligent reader will perceive that all theſe roofs are on one principle, depending on a truſs of three pieces and a ſtraight tie-beam. This is indeed the great principle of a truſs, and is a ſtep beyond the roof with two rafters and a king poſt. It admits of much greater variety of forms, and of greater extent. We may ſee, that even the middle part may be carried to any ſpace, and yet be flat at top; for the truſs-beam may be ſupported in the middle by an inverted king poſt (of timber, not iron), carried by iron or wooden ties from its extremities: And the ſame ties may carry the horizontal tie-beam K; for till K be torn aſunder, or M, M, and P be crippled, nothing can fail.

The roof of St Martin's church in the Fields is conſtructed on good principles, and every piece properly diſpoſed. But although its ſpan does not exceed 40 feet from column to column, it contains more timber in a truſs than there is in one of Drury Lane theatre. The roof of the chapel at Greenwich, that of St Paul's, Covent Garden, that of Birmingham, and that of Drury Lane theatres, form a ſeries gradually more perfect. Such ſpecimens afford excellent leſſons to the artiſts. We therefore account them a uſeful preſent to the public.

48 Project by Mr Nicholſon.

There is a very ingenious project offered to the public by Mr Nicholſon (Carpenter's Aſſiſtant, p. 68.) He propoſes iron rods for king poſts, queen poſts, and all other ſituations where beams perform the office of ties. This is in proſecution of the notions which we publiſhed in the article Roof of the *Encycl.* (ſee n° 36, 37.) He receives the feet of the braces and ſtruts in a ſocket very well connected with the foot of his iron king poſt; and he ſecures the feet of his queen poſts from being puſhed inwards, by interpoſing a ſtraining ſill. He does not even mortiſe the foot of his principal rafter into the end of the tie-beam, but ſets it in a ſocket like a ſhoe, at the end of an iron bar, which is bolted into the tie-beam a good way back. All the parts are formed and diſpoſed with the preciſion of a perſon thoroughly acquainted with the ſubject; and we have not the ſmalleſt doubt of the ſucceſs of the project, and the complete ſecurity and durability of his roofs, and we expect to ſee many of them executed. We abound in iron, but we muſt ſend abroad for building timber. This is therefore a valuable project; at the ſame time, however, let us not over-rate its value. Iron is but about 12 times ſtronger than red fir, and is more than 12 times heavier; nor is it cheaper, weight for weight, or ſtrength for ſtrength.

Our illuſtrations and examples have been chiefly taken from roofs, becauſe they are the moſt familiar inſtances of the difficult problems of the art. We could have wiſhed for more room even on this ſubject. The conſtruction of dome roofs has been (we think) miſtaken, and the difficulty is much leſs than is imagined. We mean in reſpect of ſtrength; for we grant that the obliquity

obliquity of the joints, and a general intricacy, increaſes the trouble of workmanſhip exceedingly. Another opportunity may perhaps occur for conſidering this ſubject.

49 Wooden bridges.

Wooden bridges form another claſs equally difficult and important; but our limits are already overpaſſed, and will not admit them. The principle on which they ſhould all be conſtructed, without exception, is that of a truſs, avoiding all lateral bearings on any of the timbers. In the application of this principle, we muſt farther remark, that the angles of our truſs ſhould be as acute as poſſible; therefore we ſhould make it of as few and as long pieces as we can, taking care to prevent the bending of the truſs beams by bridles, which embrace them, but without preſſing them to either ſide. When the truſs conſiſts of many pieces, the angles are very obtuſe; and the thruſts increaſe nearly in the duplicate proportion of the number of angles. The proper maxims will readily occur to the artiſt who conſiders with attention the ſpecimens of centres or coombs, which we ſhall give in the article Centre.

50 Framing of great levers.

With reſpect to the frames of carpentry which occur in engines and great machines, the varieties are ſuch that it would require a volume to treat of them properly. The principles are already laid down; and if the reader be really intereſted in the ſtudy, he will engage in it with ſeriouſneſs, and cannot fail of being inſtructed. We recommend to his conſideration, as a ſpecimen of what may be done in this way, the working beam of Hornblower's ſteam engine (ſee *Steam-Engine*, n° 84. *Encycl.)* When the beam muſt act by chains hung from the upper end of arch heads, the framing there given ſeems very ſcientifically conſtructed; at the ſame time, we think that a ſtrap of wrought iron, reaching the whole length of the upper bar (ſee the figure), would be vaſtly preferable to thoſe partial plates which the engineer has put there, for the bolts will ſoon work looſe.

But when arches are not neceſſary, the form employed by Mr Watt is vaſtly preferable, both for ſimplicity and for ſtrength. It conſiſts of a ſimple beam AB (fig. 42.), having the gudgeon C on the upper ſide. The two piſton rods are attached to wrought iron joints A and B. Two ſtrong ſtruts DC, EC reſt on the upper ſide of the gudgeon, and carry an iron ſtring ADEB, conſiſting of three pieces, connected with the ſtruts by proper joints of wrought iron. A more minute deſcription is not needed for a clear conception of the principle. No part of this is expoſed to a croſs ſtrain; even the beam AB might be ſawed through at the middle. The iron ſtring is the only part which is ſtretched; for AC, DC, EC, BC, are all in a ſtate of compreſſion. We have made the angles equal, that all may be as great as poſſible, and the preſſure on the ſtruts and ſtrings a minimum. Mr Watt makes them much lower, as A *de* B, or A δε B. But this is for economy, becauſe the ſtrength is almoſt inſuperable. It might be made with wooden ſtrings; but the workmanſhip of the joints would more than compenſate the cheapneſs of the materials.

51 Concluſion.

We offer this article to the public with deference, and we hope for an indulgent reception of our eſſay on a ſubject which is in a manner new, and would require much ſtudy. We have beſtowed our chief attention on the ſtrength of the conſtruction, becauſe it is here that perſons of the profeſſion have the moſt ſcanty information. We beg them not to conſider our obſervations as too refined, and that they will ſtudy them with care. One principle runs through the whole; and when that is clearly conceived and familiar to the mind, we venture to ſay that the practitioner will find it of eaſy application, and that he will improve every performance by a continual reference to it.

If this attempt to inſtruct our moſt valuable and much eſteemed artiſts ſhall appear to meet with their approbation, it may encourage us to engage in the ſerious taſk of compoſing a ſyſtem on the ſubject. But this is a great work, and will require much time and liberal contribution of knowledge from the eminent carpenters who do honour to this country by their works.

Carré.

CARRE' (Lewis), was, in 1663, born in the province of Brie in France; and refuſing to enter into the ſervice of the church, for which his education was intended to fit him, he incurred the diſpleaſure of his father. His reſources being thus cut off, he was obliged to quit the univerſity, and go out into the world without employment or the means of ſubſiſtence. In this exigency he was ſomehow introduced to the celebrated Malebranche, and retained by him as an amanuenſis. Under this great maſter he ſtudied mathematics and metaphyſics, and could hardly fail to become ſtrongly attached to the latter ſcience. After reſiding ſeven years with Malebranche, he reſolved to enter upon ſome employment, which might procure him a leſs precarious eſtabliſhment than what could be enjoyed by the favour of any individual: and with that view he began at Paris a courſe of lectures in mathematics, metaphyſics, and moral philoſophy, to ſuch young ladies and gentlemen as choſe to put themſelves under his tuition. When we think of the maſter under whom he himſelf ſtudied thoſe ſciences, we cannot wonder that he made geometry ſerve merely as an introduction to his beloved metaphyſics; and indeed the order of his courſe deſerves to be univerſally adopted. It is ſurely much better to accuſtom the youthful mind to ſteady apprehenſion and patient thinking in the ſtudy of the ancient geometry, before it proceed to ſciences more abſtract, than to hurry it at once, as is the practice in ſome univerſities, into all the mazes and intricacies of what is called the firſt philoſophy.

But although M. Carré gave the preference to metaphyſics, he did not neglect mathematics; and while he taught both, he took care to make himſelf acquainted with all the new diſcoveries in the latter. This was all that his conſtant attendance on his pupils would allow him to do till the year 1697, when M. Varignon ſo remarkable for his extreme ſcrupulouſneſs in the choice of his eleves, took M. Carré to him in that ſtation. Soon after, viz. in the year 1700, our author, thinking himſelf bound to do ſomething that might render him worthy of that title, publiſhed the firſt complete work on the integral calculus, under the title of " A Method of Meaſuring Surfaces and Solids, and finding their Centres of Gravity, Percuſſion, and Oſcillation." He afterwards diſcovered ſome errors in the work, and was candid enough to own and correct them in a ſubſequent edition.

In a little time M. Carré became aſſociate, and at length one of the penſioners of the Academy. And as this was a ſufficient eſtabliſhment for one who knew ſo well how to keep his deſires within juſt bounds, he gave himſelf up entirely to ſtudy; and as he enjoyed the appointment of mechanician, he applied himſelf more particularly to mechanics. He took alſo a ſurvey of every branch relating to muſic; ſuch as the doctrine of ſounds, and the deſcription of muſical inſtruments; though he deſpiſed the practice of muſic as a mere ſenſual pleaſure. Some ſketches of his ingenuity and induſtry in this way may be ſeen in the Memoirs of the French Academy of Sciences. M. Carré alſo compoſed ſome treatiſes on other branches of natural philoſophy, and ſome on mathematical ſubjects; all which he bequeathed to that illuſtrious body, though it does not appear that any of them have yet been publiſhed. It is not unlikely that he was hindered from putting the laſt hand to them by a train of diſorders proceeding from a bad digeſtion, which, after harraſſing him during the ſpace of five or ſix years, at length brought him to the grave in 1711, at 48 years of age.

Though he poſſeſſed a conſiderable degree of ſcience and much ingenuity, like many other eminent men he had neglected in his youth to ſtudy the language of his native country. In conſequence of this, one of the earlieſt of his female pupils, perceiving that his language was the reverſe of elegant, told him pleaſantly, that as an acknowledgment for the trouble which he had taken to teach her philoſophy, ſhe would in return teach him French; and he ever afterwards ſaid, that from her leſſons he had reaped great advantage. To this circumſtance probably it was owing that he thought more highly of the genius of women than that of men.

The following is a chronological liſt of his memoirs printed in the volumes of the Academy.

1. The rectification of curve lines by tangents, 1701. 2. Solution of a problem propoſed to geometricians, &c. 1701. 3. Reflections on the table of equations, 1701. 4. On the cauſe of the refraction of light, 1702. 5. Why the tides are always augmenting from Breſt to St Malo, and diminiſhing along the coaſts of Normandy, 1702. 6. The number and the names of muſical inſtruments, 1702. 7. On the vinegar which cauſes ſmall ſtones to roll upon an inclined plane, 1703. 8. On the rectification, &c. of the cauſtics by reflection, 1703. 9. Method for the rectification of curves, 1704. 10. Obſervations on the production of ſound, 1704. 11. On a curve formed from a circle, 1705. 12. On the refraction of muſket-balls in water, and on the reſiſtance of that fluid, 1705. 13. Experiments on capillary tubes, 1705. 14. On the proportion of pipes to have a determinate quantity of water, 1705. 15. On the laws of motion, 1706. 16. On the properties of pendulums, with ſome new properties of the parabola, 1707. 17. On the proportion of cylinders, that their ſounds may form the muſical cords, 1709. 18. On the elaſticity of the air, 1710. 19. On catoptrics, 1710. 20. On the Monochord: in the *Machines*, tom. 1. with ſome other pieces, not mathematical.

CARTERET, a maritime co. of Newbern diſtrict, N. Carolina, on Core and Pamlico Sounds. It contains 3732 inhabitants, including 713 ſlaves. Beaufort is the chief town.—*Morſe.*

CASCABEL, the knob or button of metal behind the breech of a cannon, as a kind of handle by which to elevate and direct the piece; to which ſome add the fillet and ogees as far as the baſe-ring.

CASCO *Bay*, in the diſtrict of Maine, ſpreads N. W. between Cape Elizabeth on the S. W. and Cape Small Point on the N. E. Within theſe points, which are about 40 miles apart, are about 300 ſmall iſlands, ſome of which are inhabited, and nearly all more or leſs cultivated. The land on theſe iſlands, and on the oppoſite coaſt on the main, is the beſt for agriculture of any on the ſea coaſt of this country. Caſco includes ſeveral bays. *Maquoit Bay* lies about 20 miles N. of Cape Elizabeth. The waters of Caſco extend ſeveral arms or creeks of ſalt water into the country. The waters go up *Meadows River*, where veſſels of a conſiderable ſize are carried by the tide, and where it flows within one mile of the waters of Kennebeck. On the E. ſide of Cape Elizabeth is the arm of the ſea called *Stroudwater*. Farther E. is *Preſumpſcot River* formerly called Preſumpca, or Preſumpkeag, which riſes in Sebago Pond. This river opens to the waters of Caſco Bay on the E. of Portland; its extent is not great, but it has ſeveral valuable mills upon it. *Rayal's River* called by the natives Weſtecuſtego, falls into the bay 6 miles from Preſumpſcot River. It has a good harbor at its mouth for ſmall veſſels; and has ſeveral mills upon it; 2 miles higher a fall obſtructs the navigation. Between it and Kennebeck there are no rivers; ſome creeks and harbors of Caſco Bay throw themſelves into the main land, affording harbors for ſmall veſſels, and interſecting the country in various forms.—*Morſe.*

CASEMATE, or CAZEMATE, in fortification, a kind of vault or arch of ſtone-work, in that part of the flank of a baſtion next the curtain; ſerving as a battery to defend the face of the oppoſite baſtion, and the moat or ditch.

It is now ſeldom uſed, becauſe the batteries of the enemy are apt to bury the artillery of the caſemate in the ruins of the vault; beſide, the great ſmoke made by the diſcharge of the cannon renders it intolerable to the men. So that, inſtead of the ancient covered caſemates, later engineers have contrived open ones, only guarded by a parapet, &c.

CASEMATE is alſo uſed for a well with ſeveral ſubterraneous branches, dug in the paſſage of the baſtion, till the miner is heard at work, and air given to the mine.

CASSINI (James), a celebrated French aſtronomer, was born at Paris February 18. 1677, being the younger ſon of Johannes Dominicus Caſſini, of whom ſome account has been given in the *Encyclopædia*.

After his firſt ſtudies in his father's houſe, in which it is not to be ſuppoſed that mathematics and aſtronomy would be neglected, he was ſent to ſtudy philoſophy at the Mazarine college, where the celebrated Varignon was then profeſſor of mathematics. From the aſſiſtance of this eminent man young Caſſini profited ſo well, that at 15 years of age he ſupported a mathematical theſis with great honour. At the age of 17 he was admitted a member of the Academy of Sciences; and the ſame year he accompanied his father in a journey to Italy, where he aſſiſted him in the verification of the meridian at Bologna and other meaſurements. On his return he performed ſimilar operations in a journey into Holland, where he diſcovered ſome errors in the meaſure of the earth by Snell the reſult of which was communicated to the Academy in 1702. He made alſo a viſit to England in 1696, where he was made a member of the Royal Society. In 1712 he ſucceeded his father as aſtronomer royal at the obſervatory of Paris. In 1717 he gave to the Academy his reſearches on the diſtance of the fixed ſtars; in which he ſhewed that the whole annual orbit, of near 200 millions of miles diameter, is but as a point in compariſon of that diſtance. The ſame year he communicated alſo his diſcoveries concerning the inclination of the orbits of the ſatellites in general, and eſpecially of thoſe of Saturn's ſatellites and ring. In 1725 he undertook to determine the cauſe of the moon's libration, by which ſhe ſhews ſometimes a little towards one ſide, and ſometimes a little on the other, of that half which is commonly behind or hid from our view.

In 1732 an important queſtion in aſtronomy exerciſed the ingenuity of our author. His father had determined, by his obſervations, that the planet Venus revolved about her axis in the ſpace of 23 hours; and M. Bianchini had publiſhed a work in 1729, in which he ſettled the period of the ſame revolution at 24 days 8 hours. From an examination of Bianchini's obſervations which were upon the ſpots in Venus, he diſcovered that he had intermitted his obſervations for the ſpace of three hours, from which cauſe he had probably miſtaken new ſpots for the old ones, and ſo had been led into the miſtake. The probability is, that both had fallen into ſome miſtake, or that they had proceeded on very different principles; for otherwiſe ſuch different reſults are wholly unaccountable. Dr Herſchel ſeems ſatisfied that the period of the revolution is leſs than Bianchini has made; but he does not ſay what it is, or that it is not much greater than it was ſuppoſed by Caſſini. Our author, after he had convicted Bianchini, as he thought, of error, determined the nature and quantity of the acceleration of the motion of Jupiter at half a ſecond per year, and of that of the retardation of Saturn at two minutes per year; that theſe quantities would go on increaſing for 2000 years, and then would decreaſe again. In 1740 he publiſhed his Aſtronomical Tables, and his Elements of Aſtronomy; very extenſive and accurate works.

Although aſtronomy was the principal object of our author's conſideration, he did not confine himſelf abſolutely to that branch, but made occaſional excurſions into other fields. We owe alſo to him, for example, Experiments on Electricity, or the Light produced by Bodies by Friction; Experiments on the Recoil of Fire-arms; Reſearches on the Riſe of the Mercury in the Barometer at different Heights above the Level of the Sea; Reflections on the perfecting of Burning-glaſſes; and other Memoirs.

The French Academy had properly judged, that one of its moſt important objects was the meaſurement of the earth. In 1669 Picard meaſured a little more than a degree of latitude to the north of Paris; but as that extent appeared too ſmall from which to conclude the whole circumference with ſufficient accuracy, it was reſolved to continue that meaſurement on the meridian of Paris to the north and the ſouth, through the whole extent of the country. Accordingly, in 1683, the late M. de la Hire continued that on the north ſide of Paris, and the older Caſſini that on the ſouth ſide. The latter was aſſiſted in 1700 in the continuation of this operation by his ſon our author. The ſame work was farther continued by the ſame academicians; and, finally, the part left unfiniſhed by De la Hire in the north was finiſhed in 1718 by our author, with the late Maraldi, and De la Hire the younger.

Theſe operations produced a conſiderable degree of preciſion. It appeared alſo, from this meaſured extent of ſix degrees, that the degrees were of different lengths in different parts of the meridian; and in ſuch ſort that our author concluded, in the volume publiſhed for 1718, that they decreaſed more and more towards the pole, and that therefore the figure of the earth was that of an oblong ſpheroid, or having its axis longer than the equatorial diameter. He alſo meaſured the perpendicular to the ſame meridian, and compared the meaſured diſtance with the differences of longitude as before determined by the eclipſes of Jupiter's ſatellites: whence he concluded that the length of the degrees of longitude was ſmaller than it would be on a ſphere, and that therefore again the figure of the earth was an oblong ſpheroid, contrary to the determination of Newton by the theory of gravity. Though Newton was of all men the moſt averſe from controverſy, the other mathematicians in Britain did not tamely ſubmit to concluſions in direct oppoſition to the fundamental doctrine of a philoſopher of whoſe talents the nation was juſtly proud. The conſequence was, that the French government ſent two different ſets of meaſurers, the one to meaſure a degree at the equator, the other at the polar circle; and the compariſon of the whole determined the figure to be an oblate ſpheroid, contrary to Caſſini's determination.

After a long and laborious life, James Caſſini died in April 1756, in conſequence of a fall, and was ſucceeded in the Academy and Obſervatory by the ſubject of the following article. He publiſhed, A Treatiſe on the Magnitude and Figure of the Earth; as alſo, The Elements or Theory of the Planets, with Tables; beſide an infinite number of papers in the Memoirs of the Academy, from the year 1699 to 1755.

CASSINI *de Thury* (Ceſar François), a celebrated French aſtronomer, director of the obſervatory, penſioner aſtronomer, and member of moſt of the learned ſocieties of Europe, was born at Paris June 17. 1714, being the ſecond ſon of James Caſſini, the ſubject of the preceding memoir, whoſe occupations and talents he inherited and ſupported with great honour. He received his firſt leſſons in aſtronomy and mathematics from MM. Maraldi and Camus; and made ſuch a rapid progreſs, that when he was not more than ten years of age he calculated the phaſes of a total eclipſe of the ſun. At the age of eighteen he accompanied his father in his two journeys undertaken for drawing the perpendicular to the obſervatory meridian from Straſbourg to Breſt. From that time a general chart of France was deviſed; for which purpoſe it was neceſſary to traverſe the country by ſeveral lines parallel and perpendicular to the meridian of Paris, and our author was charged with the conduct of this buſineſs; in which he was ſo ſcrupulous as to meaſure again what had been meaſured by his father. This great work was publiſhed in 1740, with a chart ſhewing the new meridian of Paris, by two different ſeries of triangles, paſſing along the ſea coaſts to Bayonne, traverſing the frontiers of Spain to the Mediterranean and Antibes, and thence along the eaſtern limits of France to Dunkirk, with parallel and perpendicular lines deſcribed at the diſtance of 6000 toiſes from one another, from ſide to ſide of the country.

A tour which, in 1741, our author made in Flanders, in the train of the king, gave riſe, at his majeſty's inſtance, to the chart of France; relative to which Caſſini publiſhed different works, as well as a great number of the ſheets of the chart itſelf. In 1761 he undertook an expedition into Germany, for the purpoſe of continuing to Vienna the perpendicular of the Paris meridian; to unite the triangles of the chart of France with the points taken in Germany; to prepare the means of extending into that country the ſame plan as in France; and thus to eſtabliſh ſucceſſively for all Europe a moſt uſeful uniformity.—Our author was at Vienna the 6th of June 1761, the day of the tranſit of the planet Venus over the ſun, of which he obſerved as much as the ſtate of the weather would permit him to do, and publiſhed the account of it in his *Voyage en Allemagne*.

Finally, M. Caſſini, always meditating the perfection of his grand deſign, profited of the peace of 1783 to propoſe the joining of certain points taken upon the Engliſh coaſt with thoſe which had been determined on the coaſt of France, and thus to connect the general chart of the latter with that of the Britiſh iſles, like as he had before united it with thoſe of Flanders and Germany. The propoſal was favourably received by the Engliſh government, and preſently carried into effect under the direction of the Royal Society, the execution being committed to the late General Roy. See the life of that general in this *Supplement*.

Between the years 1735 and 1770, M. Caſſini publiſhed, in the volumes of Memoirs of the French Academy, a prodigious number of pieces, conſiſting chiefly of aſtronomical obſervations and queſtions; among which are obſervable, reſearches concerning the parallax of the ſun, the Moon, Mars, and Venus; on aſtronomical refractions, and the effect cauſed in their quantity and laws by the weather; numerous obſervations on the obliquity of the ecliptic, and on the law of its variations. In ſhort, he cultivated aſtronomy for fifty years, the moſt important for that ſcience that ever elapſed for the magnitude and variety of objects, in which he commonly ſuſtained a principal ſhare.

M. Caſſini was of a very ſtrong and vigorous conſtitution, which carried him through the many laborious operations in geography and aſtronomy which he conducted. An habitual retention of urine, however, rendered the laſt twelve years of his life very painful and diſtreſſing, till it was at length terminated by the ſmall-pox the 4th of September 1784, in the 71ſt year of his age. He was ſucceeded in the academy, and as director of the obſervatory, by his only ſon John-Dominic Caſſini, the fourth in order of direct deſcent who has filled that honourable ſtation.

CASTINE, the ſhire town of Hancock co. diſtrict of Maine, is ſituated on Penobſcot bay. It was taken from the town of Penobſcot, and incorporated in Feb. 1796. It is named after a French gentleman who reſided here 130 years ago, as alſo

CASTINE *River*, which is about 14 miles long, is navigable for 6 miles, and has ſeveral mills at the head of it. It empties into Penobſcot bay.—*Morſe.*

CASTLETON, a townſhip and river in Rutland co. Vermont, 20 miles S. E. of Mount Independence, at Ticonderoga. Lake Bombazon is chiefly in this town and ſends its waters into Caſtleton River which, riſing in Pittsford, paſſes through this town in a S. weſterly courſe, and falls into Pultney River in the town of Fairhaven, a little below Col. Lyon's iron works. Fort Warner ſtands in this town. Inhabitants 805.—*ib.*

CASTRAMETATION, the art or act of encamping an army.

CASWELL *Co.* in Hillſborough diſtrict, N. Carolina, borders on Virginia N. It contains 10,096 inhabitants, of whom 2,736 are ſlaves. Leeſburg is the chief town.—*Morſe.*

CATABAW *Indians*, a ſmall tribe who have one town called Catabaw, ſituated on the river of that name, N. lat. 34. 49. on the boundary line between N. and S. Carolina, and contains about 450 inhabitants, of which about 150 are fighting men. They are the only tribe which reſides in the ſtate: 144,000 acres of land were granted them by the proprietary government. Theſe are the remains of a formidable nation, the braveſt and moſt generous enemy the ſix nations had; but they have degenerated ſince they have been ſurrounded by the whites.—*ib.*

CATACAUSTICS, or CATACAUSTIC CURVES, in the higher geometry, are the ſpecies of cauſtic curves formed by reflection.

CATACOUSTICS, or CATAPHONICS, is the ſcience of reflected ſounds; or that part of acouſtics which treats of the properties of echoes.

CATALOGUES OF BOOKS, is a ſubject of which a very curious hiſtory has been given to the world by Profeſſor Beckmann. In the Encyclopædia mention has been made of ſome of the moſt valuable catalogues, their defects pointed out, and rules given for making them more perfect; but nothing has there been ſaid of their origin, or of the uſes which might be made of the oldeſt catalogues.

According to the Profeſſor, George Willer, whom ſome improperly call Viller, and others Walter, a bookſeller at Augſburg, who kept a very large ſhop, and frequented the Franckfort fairs, firſt fell upon the plan of cauſing to be printed, before every fair, a catalogue of all the new books, in which the ſize and printers names were marked. Le Mire, better known under the name of Miræus, ſays, that catalogues were firſt printed in the year 1554; but Labbe (A), Reimann (B) and Heumann (C), who took their information from Le Mire, make the year erroneouſly to be 1564.

(A) Labbe, Bibliotheca Bibliothecarum. Lipſiæ, 1682, 12mo, p. 112.

(B) Einleitung in die *Hiſtoriam Literariam*, i. p. 203.

(C) Conſpectus Reip. Litter. c. vi. § 2. p. 316.

Catalogues.

Willer's catalogues were printed till the year 1592 by Nicol. Baſſæus, printer at Franckfort. Other bookſellers, however, muſt have ſoon publiſhed catalogues of the like kind, though that of Willer continued a long time to be the principal.

In all theſe catalogues, which are in quarto and not paged, the following order is obſerved. The Latin books occupy the firſt place, beginning with the Proteſtant theological works, perhaps becauſe Willer was a Lutheran; then come the Catholic; and after theſe, books of juriſprudence, medicine, philoſophy, poetry, and muſic. The ſecond place is aſſigned to German books, which are arranged in the ſame manner.

The bookſellers of Leipſic ſoon perceived the advantage of catalogues, and began not only to reprint thoſe of Franckfort, but alſo to enlarge them with many books which had not been brought to the fairs in that city. Our author had for ſome time in his cuſtody, *Catalogus univerſalis pro nundinis Francofurtenſibus vernalibus, de anno* 1600; or, A catalogue of all the books on ſale in Book-ſtreet, Franckfort, and alſo of the books publiſhed at Leipſic, which have not been brought to Franckfort, with the permiſſion of his highneſs the elector of Saxony, to thoſe new works which have appeared at Leipſic. Printed at Leipſic by Abraham Lamberg, and to be had at his ſhop. On the September catalogue of the ſame year, it is ſaid that it is printed from the Franckfort copy with additions. He found an Imperial privilege for the firſt time on the Franckfort September catalogue of 1616: *Cum gratia et privilegio ſpeciali ſ. caeſ. maj. Proſtat. apud J. Krugerum Auguſtanum.*

Reimmann ſays, that after Willer's death the catalogue was publiſhed by the Leipſic bookſeller Henning Groſſe, and by his ſon and grandſon. The council of Franckfort cauſed ſeveral regulations to be iſſued reſpecting catalogues; an account of which may be ſeen in D. Orth's *Treatiſe on the Imperial Fairs at Franckfort.* After the buſineſs of book-ſelling was drawn from Franckfort to Leipſic, occaſioned principally by the reſtrictions to which it was ſubjected at the former by the cenſors, no more catalogues were printed there; and the ſhops in Book-ſtreet were gradually converted into taverns (A).

"In the 16th century there were few libraries; and theſe, which did not contain many books, were in monaſteries, and conſiſted principally of theological, philoſophical, and hiſtorical works, with a few, however, on juriſprudence and medicine; while thoſe which treated of agriculture, manufactures, and trade, were thought unworthy of the notice of the learned, or of being preſerved in large collections. The number of theſe works was, nevertheleſs, far from being inconſiderable; and at any rate, many of them would have been of great uſe, as they would have ſerved to illuſtrate the inſtructive hiſtory of the arts. Catalogues which might have given occaſion to inquiries after books, that may be ſtill ſomewhere preſerved, have ſuffered the fate of tombſtones, which, being waſted and crumbled to pieces by the deſtroying hand of time, become no longer legible. A complete ſeries of them perhaps is nowhere to be found, at leaſt I do not remember (ſays the Profeſſor) to have ever ſeen one in any library."

Catalogues ‖ Catalogue of the Stars.

This loſs, however, he thinks, might be in ſome meaſure ſupplied by the catalogues of Cleſs and Draudius; who, by the deſire of ſome bookſellers, collected together all the catalogues which had been publiſhed at the different fairs in different years. The work of Cleſs has the following title: *Unius ſæculi ejuſque virorum litteratorum monumentis tum florentiſſimi, tum fertiliſſimi, ab anno* 1500 *ad* 1602 *nundinarum autumnalium incluſive, elenchus conſummatiſſimus—deſumtus partim ex ſingularum nundinarum catalogis, partim ex bibliothecis.* Auctore Joanne Cleſſio, Wineccenſi, Hannoio, philoſopho ac medico.—By the editor's preface, it appears that the firſt edition was publiſhed in 1592. The order is almoſt the ſame as that obſerved by Willer in his catalogues.

The work of Draudius, which was printed in ſeveral quarto volumes for the firſt time in 1611, and afterwards in 1625, is far larger, more complete, and more methodical. Our author, however, confeſſes, that he never ſaw a perfect copy of either edition. This catalogue conſiſts of three parts; of which the firſt has the title of *Bibliotheca claſſica, ſive Catalogus officinalis, in quo ſinguli ſingularum facultatum ac profeſſionum libri, qui in quavis fere lingua extant—recenſentur; uſque ad annum* 1624 *incluſive.* Auctore M. Georgio Draudio.—It contains Latin works on theology, juriſprudence, medicine, hiſtory, geography, and politics. The copy in the library of the univerſity of Gottingen ends at page 1304, which has, however, a catch-word, that ſeems to indicate a deficiency.—The ſecond part is entitled, *Bibliotheca claſſica ſive Catalogus officinalis, in quo philoſophici artiumque adeo humaniorum, poetici etiam et muſici libri uſque ad annum* 1624 *continentur.* This part, containing Latin books alſo, begins at page 1298, and ends with page 1654, which is followed by an index of all the authors mentioned.—A ſmaller volume, of 302 pages, without an index, has for title, *Bibliotheca exotica, ſive Catalogus officinalis librorum peregrinis linguis uſualibus ſcriptorum.* And a third part, forming 759 pages, beſides an index of the authors, is called, *Bibliotheca librorum Germanicorum claſſica;* that is, A catalogue of all the books printed in the German language till the year 1625.

We have reaſon to believe that there are other editions of this catalogue than thoſe mentioned by Profeſſor Beckman; and it might become ſome prince or great man, for it is not a work for a bookſeller, to compare all the editions together, and publiſh a new one more correct than any that is at preſent extant. This indeed would be an expenſive and not an eaſy taſk; for our author obſerves, that all the oldeſt catalogues had the ſame faults as thoſe of later date, and that theſe faults have been copied by Draudius. Many books are mentioned which were never printed, and many titles, names, and dates, are given incorrectly; but Draudius nevertheleſs is well worth the attention of any one who may be inclined to employ his time and ingenuity on the hiſtory of literature; and his work certainly was of uſe to Haller when he compoſed his *Bibliotheca.*

Catalogues *of the Stars*, have uſually been diſpoſed,

(A) Joh. Adolp. Stock, Frankfurter Chronik, p. 77.

either as collected into certain figures called *conſtellations*, or according to their right aſcenſions, that is, the order of their paſſing over the meridian.

Of the principal catalogues, according to the firſt of theſe forms, an account has been given in the *Encyclopædia*. The firſt catalogue, we believe, that was printed in the new or ſecond form, according to the order of the right aſcenſions, is that of De la Caille, given in his Ephemerides for the ten years between 1755 and 1765, and printed in 1755. It contains the right aſcenſions and declinations of 307 ſtars, adapted to the beginning of the year 1750. In 1757 De la Caille publiſhed his *Aſtronomiæ Fundamenta*, containing a catalogue of the right aſcenſions and declinations of 398 ſtars, likewiſe adapted to the beginning of 1750. And in 1763, the year after his death, was publiſhed the *Cœlum Auſtrale Stelliferum* of the ſame author; containing a catalogue of the places of 1942 ſtars, all ſituated to the ſouthward of the tropic of Capricorn, and obſerved by him while he was at the Cape of Good Hope in 1751 and 1752; their places being alſo adapted to the beginning of 1750. In the ſame year was publiſhed his Ephemerides for the ten years between 1765 and 1775; in the introduction to which are given the places of 515 zodiacal ſtars, all deduced from the obſervations of the ſame author; the places adapted to the beginning of the year 1765.

In the Nautical Almanac for 1773, is given a catalogue of 387 ſtars, in right aſcenſion, declination, longitude, and latitude, derived from the obſervations of the late celebrated Dr Bradley, and adjuſted to the beginning of the year 1760. This ſmall catalogue, and the reſults of about 1200 obſervations of the moon, are all that the public have yet ſeen of the multiplied labours of this moſt accurate and indefatigable obſerver, although he has now (1798) been dead upwards of 36 years.

In 1775 was publiſhed a thin volume, intitled, *Opera Inedita*, containing ſeveral papers of the late Tobias Mayer, and among them a catalogue of the right aſcenſions and declinations of 998 ſtars, which may be occulted by the moon and planets; the places being adapted to the beginning of the year 1756.

At the end of the firſt volume of "Aſtronomical Obſervations made at the Royal Obſervatory at Greenwich," publiſhed in 1776, Dr Maſkelyne, the preſent aſtronomer royal, has given a catalogue of the places of 34 principal ſtars, in right aſcenſion and north polar diſtance, adapted to the beginning of the year 1770.

Theſe being the reſult of ſeveral years repeated obſervations, made with the utmoſt care, and the beſt inſtruments, it may be preſumed are exceedingly accurate.

In 1782, M. Bode of Berlin publiſhed a very extenſive catalogue of 5058 of the fixed ſtars, collected from the obſervations of Flamſteed, Bradley, Hevelius, Mayer, De la Caille, Meſſier, Monnier, D'Arquier, and other aſtronomers; all adapted to the beginning of the year 1780; and accompanied with a celeſtial atlas or ſet of maps of the conſtellations, engraved in a moſt delicate and beautiful manner.

To theſe may be added Dr Herſchel's catalogue of double ſtars printed in the Phil. Tranſ. for 1782 and 1783; Meſſier's nebulæ and cluſters of ſtars, publiſhed in the *Connoiſſance des Temps* for 1784; and Herſchel's catalogue of the ſame kind, given in the Phil. Tranſ. for 1786.

In 1789 Mr Francis Wollaſton publiſhed "A Specimen of a General Aſtronomical Catalogue, in Zones of North-polar Diſtance, and adapted to January 1. 1790." Theſe ſtars are collected from all the catalogues before-mentioned, from that of Hevelius downwards. This work contains five diſtinct catalogues; viz. Dr Maſkelyne's new catalogue of 36 principal ſtars; a general catalogue of all the ſtars, in zones of north-polar diſtance; an index to the general catalogue; a catalogue of all the ſtars, in the order in which they paſs the meridian; and a catalogue of zodiacal ſtars, in longitude and latitude.

Finally, in 1792, Dr Zach publiſhed at Gotha, *Tabulæ Motuum Solis*; to which is annexed a new catalogue of the principal fixed ſtars, from his own obſervations made in the years 1787, 1788, 1789, 1790. This catalogue contains the right aſcenſions and declinations of 381 principal ſtars, adapted to the beginning of the year 1800.—*Hutton's Mathematical Dictionary.*

Beſides theſe two methods of forming *catalogues* of the ſtars, Dr Herſchel has conceived a new one, in which the comparative brightneſs of the ſtars is accurately expreſſed. It is long ſince aſtronomers were firſt led to arrange the ſtars in claſſes of different magnitudes by their various degrees of brilliancy or luſtre. Brightneſs and ſize have at all times been conſidered as ſynonymous terms; ſo that the brighteſt ſtars have been referred to the claſs comprehending thoſe of the firſt magnitude; and as the ſubſequent orders of ſtars have been ſuppoſed to decreaſe in luſtre, their magnitude has been determined in the ſame decreaſing progreſſion: but the want of ſome fixed and ſatisfactory ſtandard of luſtre has been the ſource of conſiderable confuſion and uncertainty in ſettling the relative magnitudes of the ſtars. A ſtar marked 1. 2m. is ſuppoſed to be between the firſt and ſecond magnitude; but 2. 1m. intimates, that the ſtar is nearly of the ſecond magnitude, and that it partakes ſomewhat of the luſtre of a ſtar of the firſt order. Such ſubdiviſions may be of ſome uſe in aſcertaining ſtars of the firſt, ſecond, and third claſſes; but the expreſſions 5m, 5.6m, 6.5m, 6m, muſt be very vague and indefinite. Dr Herſchel obſerves that he has found them ſo in fact; and he therefore conſiders this method of pointing out the different luſtre of ſtars as a reference to an imaginary ſtandard. If any dependence could be placed on this method of magnitudes, "it would follow, that no leſs than eleven ſtars in the conſtellation of the Lion, namely, β σ π ξ A *b c d* 54, 48, 72, had all undergone a change in their luſtre ſince Flamſteed's time: For if the idea of magnitudes had been a clear one, our author, who marked β 1.2m. and γ 2m. ought to be underſtood to mean that β is larger than γ; but we now find that actually γ is larger than β. Every one of the eleven ſtars (ſays Dr Herſchel) which I have pointed out may be reduced to the ſame contradiction."

The author has pointed out the inſtances of the inſufficiency of this method, and of the uncertain concluſions that are deduced from it in determining the comparative brightneſs of ſtars found not only in Mr Flamſteed's catalogue, but alſo in the catalogues of other aſtronomers. It is ſufficiently apparent that the preſent method of expreſſing the brightneſs of the ſtars is very defective.

phabetical order, with the comparative brightneſs of the ſtars accurately ſtated. In a ſubſequent paper, publiſhed in the ſame volume, he has completely verified the utility of his method by experience, and ſhewn that there is no permanent change of luſtre in the ſtars. In the notes to his firſt catalogue he mentioned α Herculis as a periodical ſtar. By a ſeries of obſervations on this ſtar, compared with κ Ophiuchi, which was moſt conveniently ſituated for his purpoſe, he has been able not only to confirm this opinion, but to aſcertain its period. His obſervations are arranged in a table, by means of which he determines that this ſtar had gone through four ſucceſſive changes in an interval of 241 days; and therefore the duration of its period muſt be about 60 days and a quarter. This fact concurs with other circumſtances in evincing the rotatory motion of the ſtars on their axes. "Dark ſpots, or large portions of the ſurface, leſs luminous than the reſt, turned alternately in certain directions, either towards or from us, will account for all the phenomena of periodical changes in the luſtre of the ſtars, ſo ſatisfactorily, that we certainly need not look out for any other cauſe." If it be alleged that the periods in the change of luſtre of ſome ſtars, ſuch as Algol, β Lyræ, δ Cephei, and η Antinoi, are ſhort, being only 3, 5, 6, and 7 days reſpectively; while thoſe of ο Ceti, and of the changeable ſtar in Hydra, and that in the neck of the Swan, are long, amounting to 331, 394, and 497 days; and that we cannot aſcribe phenomena ſo different in their duration to the ſame cauſe—it may be anſwered to this objection, that the force of it is founded on our limited acquaintance with the ſtate of the heavens. To the 7 ſtars, the periodical changes of which were before known, we may now add α Herculis, which performs a revolution of its changes in 60 days.

"The ſtep from the rotation of α Herculis to that of ο Ceti is far leſs conſiderable than that from the period of Algol to the rotation of α Herculis; and thus a link in the chain is now ſupplied, which removes the objection that aroſe from the vacancy." The rotation of the fifth ſatellite of Saturn is proved by the change obſervable in its light; and "this variation of light, owing to the alternate expoſition of a more or leſs bright hemiſphere of this periodical ſatellite, plainly indicates, that the ſimilar phenomenon of a changeable ſtar ariſes from the various luſtre of the different parts of its ſurface, ſucceſſively turned to us by its rotatory motion."

Beſides, we perceive a greater ſimilarity between the ſun and the ſtars, by means of the ſpots that muſt be admitted to exiſt on their ſurfaces, as well as on that of the ſun.

Dr Herſchel farther obſerves, that the ſtars, beſides a rotatory motion on their axes, may have other movements; "ſuch as nutations or changes in the inclination of their axes; which, added to bodies much flattened by quick rotatory motions, or ſurrounded by rings like Saturn, will eaſily account for many new phenomena that may then offer themſelves to our extended views." To this paper is likewiſe ſubjoined a catalogue of nine conſtellations; and the author promiſes to give the whole of them in ſucceſſive ſhort catalogues on the ſame plan.

CATAWESSY, a townſhip in Northumberland co. Pennſylvania, ſituated on the S. E. bank of the E. branch of Suſquehannah River oppoſite the mouth of Fiſhing Creek, and about 20 miles N. E. of Sunbury. —*Morse.*

CATENARIA, or CATENARY CURVE. See *Encycl.* and ARCH in this *Supplement.*

CATHARINE II. empreſs of all the Ruſſias, acted ſo conſpicuous a part on the theatre of the world; poſſeſſed ſuch uncommon powers of mind, highly cultivated by ſcience and literature; and was ſuch a patroneſs of ſcience and literature in others—that it cannot be deemed foreign from a work of this nature to give ſome account of the principal events of her more private life.

SOPHIA AUGUSTA FREDERICA, who, upon her marriage to the grandſon of Peter the Great, aſſumed the name CATHARINE ALEXIEVNA, was born at *Stettin* on the 2d of May 1729. Her father was Chriſtian Auguſtus, prince of Anhalt Zerbſt-Dornburg, at that time major-general in the Pruſſian ſervice, commander in chief of the regiments of infantry, and governor of the town and fortreſs of Stettin. Her mother, who was born princeſs of Holſtein Eutin, was a woman of great parts and beauty, of nearly the ſame age with the prince royal of Pruſſia, afterwards Frederic the Great, with whom ſhe kept up a regular correſpondence, and who afterwards contributed to the aggrandiſement of her daughter. This accompliſhed princeſs took upon herſelf the care of educating the young Sophia, whom ſhe brought up in the ſimpleſt manner, and would not ſuffer to exhibit the leaſt ſymptoms of that pride to which ſhe had ſome propenſity from her earlieſt childhood. The conſequence of this ſalutary reſtraint was, that good humour, intelligence, and ſpirit, were even then the ſtriking features of her youthful character. Being naturally addicted to reading, to reflection, to learning, and to employment, ſhe was taught the French and other faſhionable languages; and was inſtructed to read ſuch books chiefly as might make her acquainted with hiſtory and with the principles of ſcience; whilſt the doctrines of the Lutheran religion were carefully explained to her by a divine, who little thought how ſoon his illuſtrious pupil would embrace another faith.

The empreſs Elizabeth, who then ſwayed the ſceptre of Ruſſia, had in early life been promiſed in marriage to the young prince of Holſtein-Eutin, brother to the princeſs of Anhalt Zerbſt; but at the inſtant when the marriage was about to be celebrated, the prince fell ſick and died. Elizabeth, who loved him to exceſs, became inconſolable, and in the bitterneſs of her grief made a vow of celibacy. This vow, though ſenſual, and even laſcivious, ſhe kept ſo far as never publicly to acknowledge any man as a huſband; and upon her aſcending the throne of her anceſtors, ſhe called her nephew the Duke of Holſtein Gottorp to her court, where he was ſolemnly proclaimed, when fourteen years of age, Grand Duke, with the title of Imperial Highneſs, and declared ſucceſſor to the Empreſs Elizabeth. To ſecure the ſucceſſion in the family of Peter the Great, the Empreſs was very deſirous to have her nephew married; and the princeſs of Anhalt Zerbſt, not ignorant of the tender remembrance which ſhe ſtill preſerved for her brother, conceived the idea of placing, by means of it, her daughter on the throne of Ruſſia. She communicated her plan to the king of Pruſſia, who not only applauded it, but lent her his aſſiſtance to carry it into execution.

Full of ambitious hopes, therefore, the princeſs repaired with her daughter to St Peterſburgh, where ſhe was received with friendſhip by Elizabeth, and where the young Sophia ſoon made a conſiderable impreſſion on the mind of the Grand Duke. As Peter was well made, of a good figure, and, though uneducated, not deſtitute of natural talents, the attachment became reciprocal; and the princeſs of Zerbſt, throwing herſelf at the feet of the empreſs, aſſured her, that the two lovers were attached to each other by a paſſion unconquerable; and calling to her mind the love which ſhe had herſelf borne to the prince of Holſtein, conjured her to promote the happineſs of that prince's niece. The ſtratagem ſucceeded. The choice of Elizabeth was next day announced to the council and to the foreign miniſters; and preparations were made for celebrating the marriage with a magnificence worthy of the heir of the throne of the Ruſſias. In the mean time the Grand Duke was ſeized with the ſmall pox, from which, though he recovered, it was with ſuch a change of features, as rendered him, from being comely, almoſt hideous, and converted the love of the young princeſs of Anhalt, if indeed ſhe ever felt for him that paſſion, into horror and diſguſt. She was not, however, of a diſpoſition to let a disfigured countenance frighten her from a throne. She embraced the Greek religion, changed her name from Sophia Auguſta Frederica to Catharina Alexievna, and with the entire approbation of Elizabeth was married to her nephew the Grand Duke.

For ſome time this ill matched pair lived together, though without love, yet on terms apparently decent; but a mutual diſlike gradually took place between them, which the courtiers quickly diſcovered, and were at pains to foment into hatred. Peter was now ugly and his mind was uninformed. Catharine, if not a beauty, was at leaſt a lovely woman, and highly accompliſhed. She could find no entertainment in his converſation, and he felt himſelf degraded by her ſuperiority. A faction was formed at court, headed by the great chancellor Beſtucheff, to exclude the Grand Duke from the throne, and to place Catharine at the head of affairs; and to accompliſh this end, every art was employed to fill the feeble mind of the empreſs with jealouſies of her nephew, and with a contempt of his character. He was repreſented at one time as extremely ambitious, and capable of the moſt daring enterpriſes, to get immediate poſſeſſion of the throne; and at another, as a wretch given up to drunkenneſs and to every unprincely vice.

The conſequence of the firſt of theſe accuſations was, that he was kept at a diſtance from his aunt, and a ſtranger to public affairs; and being wholly unemployed, that time which his education had not fitted him to fill up with reading, reflection, and rational converſation, hung ſo heavy on his mind, that it was no difficult matter for thoſe diſſipated young men, who were placed about him for that very purpoſe, to initiate him in the habits of drunkenneſs and the other mean practices to which it was pretended he had long been devoted. In ſuch a ſchool, it was no wonder that he became a proficient in grovelling diſſipation: or that, being unpoliſhed, and even of rude manners, he choſe for his companions ſome of the loweſt of the people.

Catharine, in the mean time, languiſhed for that happineſs which ſhe could not find in the ſociety of her huſband. She was fond of pleaſure; but it was that comparatively refined pleaſure which ſhe had enjoyed at the court of Berlin. She loved balls, muſic, and elegant converſation, and could take no ſhare in the drunken revels of Peter. Among the young men with whom he was ſurrounded, his chamberlain Soltikoff was particularly remarked for the elegance of his taſte and the graces of his perſon; and though yet ſcarcely more than a boy in years, he was ſaid to have obtained the favours of ſeveral ladies of the court. Succeſs had made him confident and ambitious; and his ambition prompted him to aſpire at making a conqueſt even of the Grand Ducheſs. By ſtudying her taſte, and contriving to amuſe her, he was at laſt ſucceſsful; and obtained from her Imperial Highneſs every favour which he could wiſh; but he enjoyed not his fortune with moderation, and his enemies contrived to get him placed in an honourable office at a diſtance from the court. He was commiſſioned to repair to Stockholm, with the title of Envoy Extraordinary, to notify to the king of Sweden the birth of Paul Petrovitch, of whom the Grand Ducheſs had juſt been delivered.* The preſumptuous Soltikoff, proud of the employment, ſet off with haſte to Sweden, and left it with equal ſpeed. But ſcarcely had he quitted Stockholm, on the wings of love and ambition, when he was ſtopped on the road by a courier, who put into his hands an order for him to go immediately to Hamburgh, and there to reſide in the quality of miniſter plenipotentiary from the court of Ruſſia.

Catharine for ſome time preſerved her attachment to the exiled chamberlain: but all at once the preſence of a ſtranger, whom fortune had brought to the court of Ruſſia, made her forget the lover whom ſhe no longer ſaw. This perſon was Staniſlaus Poniatowſky, the late king of Poland, who firſt made his appearance at St Peterſburg in the train of the Britiſh ambaſſador, and very quickly gained the affections of the Grand Ducheſs. In carrying on this intrigue, the lovers were not ſo cautious as to deceive the eyes of the envious courtiers, who reported to the empreſs not only all that they ſaw, but whatever they ſuſpected. Elizabeth was incenſed, and commanded Poniatowſky to quit without delay the dominions of Ruſſia. The accompliſhed Pole obeyed; but ſoon returned clothed with a character which made him in ſome degree independent of the empreſs.

The Count de Bruhl, then prime miniſter to the king of Poland, ſaw of what importance it was to his maſter to have a powerful intereſt at the court of Ruſſia. He was likewiſe no ſtranger to the paſſion which the Grand Ducheſs entertained for Poniatowſky; and having got that nobleman decorated with the order of the White Eagle, he ſent him back to St Peterſburgh in the quality of miniſter plenipotentiary from the republic and king of Poland. Nor was this all that Bruhl did for the two lovers. Being informed by the chancellor Beſtucheff, that the Grand Duke and Grand Ducheſs were languiſhing in a penury unworthy of their rank, he remitted to Poniatowſky 6000 ducats, to be employed in ſuch a manner as he might judge beſt for ſecuring the favour of the prince and his conſort. The ambaſſador profited by theſe counſels and benefactions. He was already ſure of the Grand Ducheſs's heart, and he very quickly gained the favour of her huſband. He

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* Oct. 1. 1754.

talked Engliſh and German with him; drank, ſmoked, abuſed the French, and extolled the king of Pruſſia with unlimited praiſe.

The Grand Ducheſs was ſo blinded by her paſſion, that ſhe was never without Poniatowſky in her company. She devoted to him the whole of her time; and ſhe made this intimacy ſo little a ſecret, that public report was loud to her prejudice. In the mean time ſhe was delivered of the Princeſs Anne†, who lived only fifteen months. The Grand Duke was the only perſon about court who ſeemed to know nothing of what was paſſing. His whole time was occupied in copying, with ſervile affectation, the air, the manners, the tone of the king of Pruſſia; and in dreſſing a little army at Oranienbaum in the Pruſſian uniform. His eyes, however, were at laſt opened. Some of the courtiers, from hatred to the chancellor, who countenanced the intrigue between the Grand Ducheſs and the Poliſh ambaſſador, rouſed his jealouſy in order to deſtroy their enemy. They ſucceeded. He forbade his wife to be ſeen with Poniatowſky, and prevailed with the empreſs to deprive the chancellor of his office, and to baniſh him to an eſtate which he had 120 verſts beyond Moſcow.

† February 1758.

Catharine had now to ſupport at once the averſion of her huſband, the indignation of the empreſs, the inſulting diſdain of a court, which a few days before was laviſh of its aſſiduities and ſmiles; and what afflicted her moſt of all, the dread of loſing for ever her favourite Poniatowſky. Her courage, however, did not forſake her. Poniatowſky was indeed recalled, and left Ruſſia, after ſuffering ſome deſerved indignities from the Grand Duke, who about this time formed a connection with one of the daughters of the Senator Vorontzoff, brother to the new chancellor. This lady, Elizabeth Romanovna Vorontzoff, was elder ſiſter to the Princeſs Daſhkoff, who acted ſo conſpicuous a part in the revolution which ſet the crown on the head of Catharine. She was beautiful, but vain; and poſſeſſed not either the wit or the underſtanding of her ſiſter.

In the mean time the health of the empreſs viſibly declining, Catharine was very deſirous of being reconciled to her: but the irritated ſovereign would liſten to no accommodation, except on terms too humiliating for the haughty ſpirit of the Grand Ducheſs. Catharine, therefore, abſented herſelf from court, and aſked permiſſion to retire into Germany. This, as ſhe had foreſeen, was refuſed. Elizabeth was too fond of the young Paul Petrovitch to permit the departure of his mother, and thereby expoſe him to the danger of being at ſome future period declared illegitimate. She took the Grand Ducheſs again into favour; and it is thought, that had ſhe lived a little longer than ſhe did, ſhe would have excluded Peter from the throne, and declared Paul her immediate ſucceſſor.

While the empreſs was meditating the aggrandizement of the young prince and his mother, the Grand Duke had conceived a plan for degrading them both. He had reſolved, at the moment his aunt ſhould cloſe her eyes, to aſſemble his troops, to get himſelf proclaimed emperor, to repudiate the Grand Ducheſs, to declare the young Paul Petrovitch illegitimate, and publicly to marry his miſtreſs Elizabeth Romanovna Vorontzoff. We have ſhown elſewhere (ſee Russia, n° 72. *Encycl.*) how this plan, when almoſt ready to be carried into execution, was betrayed to Catharine, who, ever ſince her caballing with the Chancellor Beſtucheff, had reſolved, by ſome means or other, to ſnatch the ſceptre from the feeble hand of her huſband. At preſent, we believe ſhe was not acquainted with it; and though ſhe had, ſhe could not now have turned it to her advantage, as her party, ever ſince the diſgrace of Beſtucheff, was without a leader of any abilities.

Amid theſe diſtractions cauſed by the proſpect of the death of the empreſs, and the known hatred of the Grand Duke and Ducheſs to each other, Count Panin, preceptor to the young prince, devoted himſelf entirely to Catharine. He wiſhed to ſee her poſſeſſed of all the power of the empire; but he was afraid to proceed to the extremity to which ſhe propoſed to go, and to deprive Peter of the name of Emperor. He contrived therefore to procure an apparent reconciliation between the Grand Duke and his conſort, as well as between him and his aunt Elizabeth; and he had almoſt perſuaded the ſilly prince not to aſſume the ſovereign power on the death of the empreſs, till he ſhould be ſolemnly inveſted with it by a decree of the ſenate. Could he obtain this point, he knew that the power of Peter would be limited, and the authority ſecured to his wife and his ſon. He was, however, diſappointed. Catharine herſelf diſapproved of this plan, and concurred with the real friends of her huſband in adviſing him "to conform to eſtabliſhed cuſtom in aſſuming the reins of empire."

He had hardly received this advice when word was brought him that the Empreſs Elizabeth was dead (a); and the courtiers preſſed in crowds about him. He accoſted them with dignity, received the oaths of the officers of his guard, and ſeemed at once to have laid aſide his weakneſs. In an hour he got on horſeback, traverſed the ſtreets of St Peterſburg, and diſtributed money among the multitude and the ſoldiers. He had been ſo treated by his aunt, that he could not poſſibly be grieved at her death; but in paying the laſt duties to her remains, he betrayed no indecent elation. The firſt actions of his reign were prudent and patriotic, and ſuch as would have done honour to a greater prince. He appeared to be reconciled to his wife, in whoſe company he ſpent much of his time; he recalled from priſon and baniſhment 17,000 perſons, ſome of them of rank and of great talents, who had been the victims of Elizabeth's jealous timidity; he permitted the nobility to bear arms or not at their own diſcretion, freeing them at the ſame time from the extreme ſervitude under which they had been held by his immediate predeceſſors; and he aboliſhed *the ſecret committee*, an infamous inquiſitorial tribunal, which ever ſince the reign of the father of Peter the Great had been the chief engine of Ruſſian deſpotiſm.

He neglected, however, one thing; which, among the people over whom he was appointed to reign, would have contributed more to the ſecurity of his throne than all the wiſe and beneficent edicts which he had publiſhed. He made no preparations to be crowned at Moſcow. Inſtead of complying with this ancient ceremony, and humouring the prejudices of his ſuperſtitious ſubjects,

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(a) Chriſtmas-day 1761 according to the Ruſſian calendar, or the 5th of January 1762 according to ours.

jects, he thought of nothing but of war with Denmark, and of a perſonal interview with the king of Pruſſia in Germany. His admiration of that great monarch hurried him indeed into the moſt extravagant follies. Not contented with giving him peace, and entering into an offenſive and defenſive alliance with him, he had the meanneſs to ſolicit a commiſſion in his army, and to accept of the rank of major-general. Of this title he ſeemed more vain than of that of Emperor of all the Ruſſias. He conſtantly wore the Pruſſian uniform; introduced among his troops the Pruſſian diſcipline, which, though better than their own, was diſagreeable, becauſe it was new, and much more becauſe it was German; and he raiſed his uncle, a man of no military talents, and a foreigner, to the dignity of generaliſſimo of the Ruſſian armies; giving him at the ſame time the particular command of the horſe-guards, a body of men which had never before been under any command but that of the ſupreme head of the empire. Nor did his infatuated predilection for Germany, a country abhorred by the Ruſſians, ſtop even here: He diſbanded the noble guards which had placed Elizabeth on the throne, diſmiſſed the horſe-guards from the ſervice which they performed at court, and ſubſtituted his Holſtein guards in their place.

Whilſt he was thus alienating from himſelf the affections of the army, he contrived to diſguſt another order of men, whoſe attachment he ſhould have laboured above all things to retain. He was at pains to ſhew his preference of the Lutheran faith and worſhip to the doctrines and ceremonies of the Greek church; he attempted to make ſome alterations in the dreſs of the monks; he annexed great part of the poſſeſſions of the church to the domains of the crown; and he baniſhed the archbiſhop of Novogorod, who oppoſed theſe innovations; and found himſelf obliged ſuddenly to recal him.

He had now returned to his former courſes. He ſhut himſelf up for whole days with his miſtreſs and drunken companions; he compelled the nobility and ladies of the court to ſit in company with buffoons and comedians; he inſulted every foreign miniſter but the miniſters of Great-Britain and Pruſſia; and he made no ſecret of his intention to repudiate the empreſs, declare Paul Petrovitch illegitimate, and marry the Counteſs Vorontzoff. Convinced, however, as it would ſeem, that he could not be a father, he reſolved to adopt Prince Ivan, the deſcendant of the elder brother of Peter the Great, whom Elizabeth had dethroned and confined in priſon, to declare him his ſucceſſor, and to unite him in marriage with the young princeſs of Holſtein Beck, who was then at St Peterſburgh, and whom he cheriſhed as his daughter.

This inconſiſtent and weak conduct of the emperor turned the attention of all orders of men to the empreſs, who made it her ſole employment to gain thoſe hearts which he was loſing. Inſtructed from her infancy in the arts of diſſimulation, it was not difficult for her to affect, in the ſight of the multitude, ſentiments the moſt foreign to her mind. The pupil of the French philoſophers put on the air of a bigot to the moſt ſuperſtitious ceremonies of the Greek religion, and treated the miniſters of that religion with the profoundeſt reverence. And whilſt her huſband was getting drunk amidſt a rabble of buffoons, and diſguſting every perſon of decency who approached him, ſhe kept her court with a mixture of dignity and affability, which attracted to her all who, by capacity, courage, or reputation, were capable of ſerving her.

Correct, however, as her public conduct appeared, her private life was not leſs licentious than formerly. While yet Grand Ducheſs, ſhe had formed a very tender connection with Gregory Orloff, a man of mean birth, and of no education, but poſſeſſed at once of perſonal beauty and the moſt daring courage. He had an inferior commiſſion in the artillery, while his two brothers were common ſoldiers in the regiments of guards. The intrigue which ſhe carried on with him was known only to one of her women named Catharine Ivanovna; nor did Orloff himſelf for ſome time ſuſpect the rank of the lady who ſo laviſhly conferred upon him her favours in ſecret. At laſt finding him intrepid and diſcreet, ſhe diſcovered herſelf, unveiled to him all her ambitious deſigns, and eaſily prevailed with him and his brothers to enter with zeal into her conſpiracy againſt the emperor. Orloff likewiſe gained over Bibikoff his friend, a Lieutenant Paſſick, with other officers; and by their means eaſily ſeduced ſome regiments of the guards. The Princeſs Daſhkoff was ſtrongly attached to Catharine, we believe, from worthy motives, and had frequent meetings with Orloff on the buſineſs of the conſpiracy, without ſuſpecting that he was ſo much as known to the empreſs. Count Panin, too, and the Hetman of the Koſſacks, were determined to tumble Peter from the throne; but they were not inclined to go all the lengths propoſed by Catharine and her two favourites. Hoping to enjoy the actual power of the empire themſelves, they were for declaring Paul Petrovitch emperor in the room of his father, and conferring upon his mother the name and authority only of regent; while the princeſs and Orloff, knowing the ſentiments and wiſhes of the empreſs, were reſolved to veſt her with ſovereign power, or to periſh themſelves in the hazardous attempt.

In the mean time the anniverſary of the patron ſaints of Ruſſia was at hand, when Peter had determined, at the concluſion of the feſtival, to divorce the empreſs, ſhut her up in priſon, declare her ſon illegitimate, and publickly marry his miſtreſs. As they who plan a conſpiracy are always more vigilant than thoſe againſt whom it is directed, the friends of Catharine were carefully informed of all that paſſed about the emperor, whilſt he was kept in total ignorance of their proceedings. It was therefore neceſſary for them to unite in the ſame plan, and to carry it quickly into execution; for delay or diviſions would involve them all in one common ruin. The empreſs contrived to bring over the Hetman entirely to her views; and the Princeſs Daſhkoff, by the ſacrifice, it has been ſaid, of her charms, found little difficulty in reconciling Count Panin to the ſame meaſures. They now agreed to ſeize the Tzar on his arrival at Peterhoff, an Imperial palace on the ſhore of the Gulf of Cronſtadt, where he propoſed to celebrate the approaching feſtival; and they were waiting impatiently for the moment of action, when all at once their plot was diſcovered.

Paſſick, who has been mentioned among the conſpirators, had gained the ſoldiers of the company of guards in which he was a lieutenant; but one of them, who thought that his captain was in the ſecret, aſked that officer one evening, When they were to take up arms againſt the emperor? The captain, ſurpriſed, had recourſe to diſſimulation, and eaſily drew from the ſoldier all that he knew of the conſpiracy. It was nine o'clock at night. Paſſick was put under arreſt; but found means to ſlip into the hands of a man who had been placed as a ſpy over him by the Princeſs Daſhkoff, a ſcrap of paper containing theſe words, "Proceed to execution this inſtant, or we are undone." The man was deſired to carry it to the Hetman, by whom he would be handſomely rewarded; but he hurried with it to the princeſs, who inſtantly communicated the intelligence to the other conſpirators. She herſelf put on man's apparel, and haſtened to the place where ſhe was accuſtomed to meet Orloff and his friends; where ſhe found them, as impatient as herſelf to carry their plot into immediate execution.

During this awful criſis the empreſs was at Peterhoff, at the diſtance of 25 verſts from St Peterſburgh; and one of the brothers of Gregory Orloff, named Alexius, undertook to find her out, whilſt he himſelf, with his other brother and Bibikoff his friend, repaired to the barracks for the purpoſe of inſtructing the ſoldiers of their party how to act on the firſt ſignal. Alexius Orloff carried with him a ſhort note from the Princeſs Daſhkoff, but neglected to deliver it; and the empreſs, being ſuddenly rouſed from a ſound ſleep, was much alarmed, when ſhe ſaw at the ſide of her bed a ſoldier of whom ſhe knew nothing. Her alarm was increaſed when the ſtranger ſaid, "Your majeſty has not a moment to loſe; get ready to follow me;" and inſtantly diſappeared. She roſe, however, and calling her woman Ivanovna, they diſguiſed themſelves in ſuch a manner that they could not be known by the ſentinels about the palace; and the ſoldier returning, they hurried with him to a coach which was waiting at the garden gate. Orloff took the reins, but drove with ſuch fury that the horſes ſoon fell down; and they were obliged to travel part of the way on foot. They had not, however, gone far, when they met a light country cart; and ſhe who was aſpiring to the throne of the greateſt empire in the world, was glad to enter the capital of that empire in this humble vehicle.

It was ſeven in the morning when ſhe arrived in St Peterſburgh: and to the ſoldiers, who gathered about her in great numbers, ſhe ſaid, that "her danger had driven her to the neceſſity of coming to aſk their aſſiſtance; that the Tzar had intended, that very night, to put her and her ſon to death; and that ſhe had ſo great confidence in their diſpoſitions, as to put herſelf entirely into their hands." They immediately ſhouted, "Long live the empreſs!" And the chaplain of one of the regiments fetching a crucifix, received their oaths of fidelity.

The troops, however, were not unanimous in this revolt. Though Gregory Orloff was treaſurer of the artillery, and well enough beloved by the ſoldiers, that corps refuſed to follow him until he ſhould produce the orders of Villebois their general; and that officer, withheld either by fidelity to the emperor or by fear, preſumed to ſpeak to Catharine of the obſtacles which yet remained for her to ſurmount; adding, that ſhe ought to have foreſeen them. She haughtily replied, that "ſhe had not ſent for him to aſk what ſhe ought to have foreſeen, but to know how he intended to act." "To obey your majeſty," returned Villebois; and putting himſelf at the head of his regiment, he immediately joined the conſpirators. So ripe indeed were the minds of all men for this revolt, that in the ſpace of two hours the empreſs found herſelf ſurrounded by 2000 warriors, together with great part of the inhabitants of Peterſburgh; and with that numerous train of attendants ſhe repaired to the church of Kaſan, where the archbiſhop of Novogorod, ſetting the Imperial crown on her head, proclaimed her ſovereign of all the Ruſſias, declaring, at the ſame time, Paul Petrovitch her ſucceſſor.

Matters had now proceeded by much too far to admit of any compromiſe between Catharine and her huſband: but had the infatuated Tzar put his affairs wholly into the hands of Marſhal Munich, that intrepid veteran would have tumbled the empreſs from her throne almoſt as quickly as ſhe had got poſſeſſion of it. He acted, however, a very different part. Upon receiving intelligence of what had been done at St Peterſburgh, he aſked indeed the Marſhal's advice, but ſuffered himſelf to be guided by his miſtreſs and timid companions. Through their terrors and his own irreſolution opportunities were loſt which could never be recovered; for though his Holſtein guards, with tears in their eyes, ſwore that they were all ready to ſacrifice their lives in his ſervice, and though the old Marſhal offered to lead them againſt the rebels, ſaying to the emperor, "I will go before you, and their ſwords ſhall not reach you till they have pierced my body," he was perſuaded to treat with the empreſs, to acknowledge his miſconduct, and to offer to ſhare with her the ſovereign power. At laſt he was weak enough to abandon his troops, and to ſurrender at diſcretion to his conſort; whoſe creatures hurried him from Oranienbaum to Peterhoff, ſtripped him of all his clothes, and after leaving him for ſome time in his ſhirt, a butt to the outrages of an inſolent ſoldiery, threw over him an old morning gown, and ſhut him up alone, with a guard at the door of his wretched apartment. On the 29th of June, O. S.* 1762, Count Panin was ſent to him by the empreſs; and after a long conference, prevailed with him to write and ſign a ſolemn reſignation of his crown, and a declaration of his utter incapacity to govern ſo great an empire.

The revolution was now complete, and Peter ſeemed to enjoy ſome compoſure of mind; but in the evening he was carried a priſoner to Ropſcha, a ſmall Imperial palace, at the diſtance of 20 verſts from Peterhoff, where he was murdered on the 17th of July, juſt one week after his depoſition. Of the manner of his death different accounts have been given. By ſome he is ſaid to have been poiſoned; by others, to have been ſtrangled by one of the Orloffs; and a few have thought that he periſhed by the ſame means as Henry VI. of England. Whether the empreſs was acceſſary to his death is not known; though it is certain, that ſo far from making any inquiry after his murderers, ſhe affected to believe that he had died naturally of the *piles!*

The firſt care of Catharine was to reward thoſe who had been the principal actors in the revolt. Panin was made prime miniſter; the Orloffs received the title of Count; and the favourite Gregory was appointed lieutenant-general of the Ruſſian armies, and knight of the order of St Alexander Nefſky, the ſecond order of the empire. Several officers of the guards were promoted, of whom 24 received conſiderable eſtates; and among the

* July 1

a-year, to be paid him in England, beſides L. 10,000 which he immediately received. So popular was the empreſs at this period, that, by a decree of the ſenate, the anniverſary of her recovery from the ſmall-pox was enjoined to be celebrated as a religious feſtival; and it has ever ſince been obſerved as ſuch.

She was now engaged in war with the Turks, of which a ſufficient account for a work of this nature has been given under the title Turkey *(Encycl.)*; but there was one tranſaction of her and her friends, of which no mention was made in that article, though it is of importance to him who would form a juſt eſtimate of her perſonal character.

We have noticed the ſenſuality of the empreſs Elizabeth. She bore three children to the grand veneur Alexy Gregorievitch Razumofſky, to whom, indeed, ſhe is ſaid to have been clandeſtinely married. Of theſe children the youngeſt was a girl, brought up under the name of princeſs Tarrakanoff. Prince Radzivil, who has been mentioned in the article Poland *(Encycl.)*, irritated at Catharine's cruelties to his countrymen, conceived the project of placing the young princeſs on the throne of her anceſtors; and, having gained over the perſons to whom her education was entruſted, he carried her off to Rome as a place of ſafety. Catharine, in return, ſeized his large eſtates; and he and the princeſs were reduced to extreme poverty. Radzivil repaired to Poland in order to learn what could be done to forward his great enterpriſe; and ſcarcely had he arrived there when an offer was made to reſtore to him his poſſeſſions, upon condition of his carrying his ward to St Peterſburgh. This he refuſed; but had the baſeneſs to promiſe, that he would give himſelf no farther concern about the daughter of Elizabeth; and he was put in poſſeſſion of all his eſtates.

By the inſtructions of the empreſs, Alexius Orloff, who nominally commanded the Ruſſian fleet at the Dardanelles, repaired to Rome, got acceſs to young Tarrakanoff, and found means to perſuade her that all Ruſſia was ready to revolt from Catharine, and place her on the throne of her mother. To convince her of his ſincerity, he pretended to feel for her the tendereſt and moſt reſpectful paſſion; and the unſuſpicious lady was induced to accept of him as a huſband. The ruffian who had aſſaſſinated the grandſon of Peter the Great, did not heſitate to ſeduce and betray his granddaughter. Under pretence of having the marriage ceremony performed according to the rites of the Greek church, he ſuborned ſome ſubaltern villains to perſonate prieſts and lawyers; thus combining profanation with impoſture againſt the unprotected and too confident Tarrakanoff.

Having been treated for ſome days, both at Rome and at Leghorn, with all the reſpect due to a ſovereign, the unſuſpecting princeſs expreſſed a wiſh to go on board a Ruſſian ſhip of war. This was juſt what Orloff wanted. Attended by a numerous and obſequious train, ſhe was rowed from the ſhore in a boat with magnificent enſigns, hoiſted upon the deck of the ſhip in a ſplendid chair, and immediately handcuffed. In vain did ſhe throw herſelf at the feet of her pretended huſband, and conjure him by every thing tender which had paſſed between them. She was carried down into the hold; the next day the veſſel ſailed for St Peterſburgh; where, upon her arrival, the princeſs was ſhut up in the fortreſs; and what became of her ſince was never known. Such were the means which Catharine ſcrupled not to employ in order to get rid of all pretenders to her throne.

Soon after this ſervice rendered to her by Alexius Orloff, ſhe diſmiſſed his brother Gregory from her favour, and connected herſelf with Vaſſiltchikoff, a ſub-lieutenant of the guards. The former favourite had indeed become inſolent, and, as Catharine thought, ungrateful. He aſpired to nothing leſs than the throne. From love to himſelf and to a ſon which ſhe had born to him, ſhe offered to enter into a ſecret marriage; but with this propoſal the proud prince (A) was not ſatisfied, and hoped that his refuſal would impel her to receive him publicly as her huſband and partner in power. He was miſtaken. She diveſted him of all his employments; but gave him a penſion of 150,000 rubles, a handſome ſervice of plate, and an eſtate with 6000 peaſants upon it; and, thus enriched, he ſet out upon a journey through various parts of Europe. He returned, however, much ſooner than was expected; the new favourite was handſomely rewarded, and ſent to a diſtance; Orloff was reſtored to all his offices, and his baleful influence was again felt.

He attempted to perſuade the empreſs to diſmiſs Panin from the court; but the grand duke interpoſed in behalf of his old preceptor; and, for once, Catharine liſtened to the entreaties of her ſon. When a dreadful rebellion, under a Koſſak of the name of Pugetſhoff, who pretended to be Peter III. eſcaped from his aſſaſſins, was ſhaking the throne to its foundation—the influence of Orloff was ſuch as to prevent the empreſs, for ſome time, from employing her ableſt general againſt the rebels, becauſe that general was Panin, brother to the miniſter. Danger, however, at laſt prevailed over the favourite: Panin was ſent againſt Pugetſhoff; the rebellion was cruſhed; and Catharine found leiſure to give ſomething like a legal conſtitution to the empire. In that work, the laws and regulations eſtabliſhed for the government of the various provinces, and for the equitable adminiſtration of juſtice through the whole of her vaſt dominions, evinces the greateſt wiſdom and ſagacity in their author, as well as a proper regard to the practicable liberties and rights of men. In the capital, ſhe eſtabliſhed the moſt perfect police, by which the internal tranquillity of a great city was, perhaps, ever maintained; and whilſt her private conduct was far from correct, ſhe was acting in the capacity of ſovereign, ſo as to deſerve, indeed, the appellation of *Mother of her people.*

To follow her through all her wars and intrigues with foreign courts, would ſwell this article to the ſize of a volume. Such a narrative, too, belongs rather to the hiſtory of Ruſſia than to the memoirs of Catharine; in which it is the buſineſs of the biographer to develope the private character of the woman rather than to detail the exploits of the ſovereign. Her partition of Poland, and afterwards the annihilation of it as an in-

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(A) She had ſome time before obtained for him a patent, creating him a prince of the Roman empire.

evening of the following day, expired, in the 68th year of her age, leaving behind her the character of one of the greateſt ſovereigns that ever ſwayed a ſceptre.

After this long detail of the incidents of her life, it is needleſs to inform the reader that Catharine II. had no religion, and, of courſe, no principles of morality, which could induce her in every inſtance to do to others as ſhe would have them do to her. She was a profeſſed diſciple of the French philoſophers; by ſome of whom ſhe was ridiculed, and by others cheated. The incenſe which ſhe paid to the genius of Voltaire did not hinder him from frequently breaking his jeſts upon the autocratrix of Ruſſia and her ſucceſſive favourites; and Diderot, whom ſhe careſſed, ſold to her an immenſe library, when he poſſeſſed hardly a book, and was obliged to ranſack Germany and France for volumes to enable him to fulfil his bargain. Such is the friendſhip, and ſuch the gratitude, which ſubſiſt among the amiable pupils of nature, and the philanthropic advocates for the rights of man.

CAUDA. *Capricorni*, a fixed ſtar of the fourth magnitude, in the tail of Capricorn; called alſo, by the Arabs, *Dineb Algedi;* and γ by Bayer.

Cauda Ceti, a fixed ſtar of the third magnitude; called alſo, by the Arabs, *Dineb Kaetos;* marked β by Bayer.

Cauda Cygni, a fixed ſtar of the ſecond magnitude, in the Swan's-tail; called by the Arabs *Dineb Adigege*, or *Eldegiagich;* and marked α by Bayer.

Cauda Delphini, a fixed ſtar of the third magnitude, in the tail of the Dolphin; marked ε by Bayer.

Cauda Draconis, or Dragon's tail, the moon's ſouthern or deſcending node.

Cauda Leonis, a fixed ſtar of the firſt magnitude, in the Lion's tail; called alſo, by the Arabs, *Dineb Eleced;* and marked β by Bayer. It is called alſo *Lucida Cauda.*

Cauda Urſæ Majoris, a fixed ſtar of the third magnitude, in the tip of the Great Bear's tail; called alſo, by the Arabs, *Alalioth*, and *Benenath;* and marked η by Bayer.

Cauda Urſæ Minoris, a fixed ſtar of the third magnitude, at the end of the Leſſer Bear's tail; called alſo the *Pole Star*, and, by the Arabs, *Alrukabah;* and marked α by Bayer.

CAVENDISH, a townſhip in Windſor co. Vermont, W. of Weathersfield, on Black river, having 491 inhabitants. Upon this river, and within this townſhip, the channel has been worn down 100 feet, and rocks of very large dimenſions have been undermined and thrown down one upon another. Holes are wrought in the rocks of various dimenſions, and forms; ſome cylindrical, from 1 to 8 feet in diameter, and from 1 to 15 feet in depth; others are of a ſpherical form from 6 to 20 feet diameter, worn almoſt perfectly ſmooth, into the ſolid body of a rock.—*Morse.*

CAUSE has been defined, we think, with accuracy in the Encyclopædia, and the doctrine ſtated which we believe to be true. Objections however have been made to that doctrine, of which we have endeavoured to remove ſome, under the title Action, in this Supplement; and the doctrine itſelf has been well illuſtrated (at leaſt ſuch is our opinion) in the ſupplementary article Astronomy. We have, therefore, very little to add here on the ſubject of cauſes, though it is the moſt important ſubject which can employ the mind of man. What is the relation between a phyſical cauſe and that which is termed its effect—between heat, for inſtance, and the fuſion of metals? Is it a *neceſſary connection*, or only a *conjunction*, diſcovered by experience to be *conſtant?*

If by *neceſſary* connection be meant that kind of connection of which the contrary cannot be conceived, we do not think that the connection of any phyſical cauſe with its effect can be called neceſſary. We ſee no difficulty in conceiving, that fire, inſtead of fuſing gold, might fix mercury. This *may* indeed be impoſſible; and we might perhaps ſee the impoſſibility, did we as completely know the nature of fire and of metals as we know the relations of pure geometry. We know that the three angles of a plain triangle cannot poſſibly be either greater or leſs than two right angles; for in this compariſon nothing is hid from our mental view. We do not, however, perceive the impoſſibility of mercury being fixed, as clay is hardened, by heat; for of *heat*, and mercury, and clay, we know very little, and that little is the offspring of experience.

But if the connection between cauſe and effect be not *neceſſary*, are we not deprived of the means of demonſtrating the great fundamental truth of religion? We have nowhere ſaid, that the connection between cauſe and effect is not neceſſary; but only, that we do not perceive the neceſſary connection between what are called *phyſical* cauſes and their effects. That every event is, and muſt be, brought about by *ſome cauſe*, or ſome *agency*, we hold to be a ſelf-evident truth, which no man can deny who underſtands the terms in which it is expreſſed; but what or where the agency is, we can very ſeldom, if ever, know, except when we think of our own voluntary actions. When a change is obſerved, we cannot doubt of its being produced by ſomething: either the thing changed is animated and has produced the change by its own agency, juſt as we move our heads and legs by an act of volition; or if it be inanimated, and of itſelf incapable of agency, the change has been produced by ſomething external, denominated a *cauſe*. But all external cauſes, which are not likewiſe agents, in the proper ſenſe of the word, may be traced, we think, as effects up to ſome agency; and therefore, in our opinion, there is no real, ultimate, efficient, cauſe but mind, or that which is endued with power. In proof of this doctrine, if it need any proof, we can only refer to what has been ſaid elſewhere on our notions of *power* and of *phyſical cauſes*. See *(Encycl.)* Metaphysics n° 109, &c.—Philosophy and Physics *paſſim*—and *(Suppl.)* Action and Astronomy.

CAYAHAGA, or *Cayuga*, ſometimes called the Great river, empties in at the S. bank of lake Erie, 40 miles eaſtward of the mouth of Huron; having an Indian town of the ſame name on its banks. It is navigable for boats; and its mouth is wide, and deep enough to receive large ſloops from the lake. Near this are the celebrated rocks which project over the lake. They are ſeveral miles in length, and riſe 40 or 50 feet perpendicular out of the water. Some parts of them conſiſt of ſeveral ſtrata of different colours, lying in a horizontal direction; and ſo exactly parallel, that they reſemble the work of art. The view from the land is grand, but the water preſents the moſt magnificent proſpect of this ſublime work of nature; it is attended, however, with great danger; for if the leaſt ſtorm ariſes, the force of the ſurf is ſuch that no veſſel can eſcape being daſhed to pieces againſt the rocks. Col. Broadſhead ſuffered ſhipwreck here in the late war and loſt a number of his men, when a ſtrong wind aroſe, ſo that the laſt canoe narrowly eſcaped. The heathen Indians, when they paſs this impending danger, offer a ſacrifice of tobacco to the water.

Part of the boundary line between the U. S. A. and the Indians, begins at the mouth of Cayahoga, and runs up the ſame to the portage between that and the Tuſcarawa branch of the Muſkingum.

The Cayuga nation, conſiſting of 500 Indians, 40 of whom reſide in the United States, the reſt in Canada, receive of the ſtate of New-York an annuity of 2300 dollars, beſides 50 dollars granted to one of their chiefs, as a conſideration for lands ſold by them to the ſtate, and 500 dollars from the United States, agreeably to the treaty of 1794.—*Morſe.*

CAYUGA, a beautiful lake in Onondaga co. New-York, from 35 to 40 miles long, about 2 miles wide, in ſome places 3, and abounds with ſalmon, baſs, catfiſh, eels, &c. It lies between Seneca and Owaſco lake, and at the N. end empties into Scayace River which is the S. eaſtern part of Seneca River whoſe waters run to lake Ontario. On each ſide of the lake is a ferry houſe, where good attendance is given. The reſervation lands of the Cayuga Indians lie on both ſides of the lake, at its northern end.—*ib.*

CEDAR *Point*, a port of entry in Charles co. Maryland, on the E. ſide of Potowmac River, about 12 miles below Port Tobacco, and 96 S. by W. of Baltimore. Its exports are chiefly tobacco and Indian corn, and in 1794, amounted in value to 18,593 dollars.—*ib.*

1
Definition.

CENTER, or CENTRE, a word borrowed from the French name *ceintre* or *cintre*, given to the frame of timber by which the brick or ſtone of arched vaulting is ſupported during its erection and from which it receives its form and curvature.

2
Purpoſe of this article.

It is not our intention to deſcribe the variety of conſtructions which may be adopted in eaſy ſituations, where the arches are of ſmall extent, and where ſufficient foundation can be had in every part of it for ſupporting the frame. In ſuch caſes, the frequency of the props which we can ſet up diſpenſes with much care; and a frame of very ſlight timbers, connected together in an ordinary way, will ſuffice for carrying the weight, and for keeping it in exact ſhape. But, when the arches have a wide ſpan, and conſequently a very great weight, and when we cannot ſet up intermediate pillars, either for want of a foundation in the ſoft bottom of a river, or becauſe the arch is turned between two lofty piers, as in the dome of a ſtately cathedral—we are then obliged to reſt every thing on the piers themſelves; and the framing which is to ſupport our arch before the keyſtone is ſet, muſt itſelf be an arch, depending on the mutual abutment of its beams. One ſhould think that this view of the conſtruction of a centre would offer itſelf at the firſt, naturally derived from the erection it was to aſſiſt: but it has not been ſo. When intermediate pillars were not employed, it was uſual to frame the mould for the arch with little attention to any thing but its ſhape, and then to croſs it and recroſs it in all directions with other pieces of timber, till it was thought ſo bound together that it could be lifted in any poſition, and, when loaded with any weight, could not change its ſhape. The frame was then raiſed in a lump, like any ſolid body of the ſame ſhape, and ſet in its place. This is the way ſtill practiſed by many country artiſts, who, having no clear principles to guide them, do not ſtop till they have made a load of timber almoſt equal to the weight which it is to carry.

But this artleſs method, beſides leading the employer into great expence, is frequently fatal to the undertaker, from the unſkilfulneſs of the conſtruction. The beams which connect its extremities, are made alſo to ſupport the middle by means of poſts which reſt on them. They are therefore expoſed to a tranſverſe or croſs ſtrain, which they are not able to bear. Their number muſt therefore be increaſed, and this increaſes the load. Some of theſe croſs ſtrains are derived from beams which are preſſed very obliquely, and therefore exert a prodigious thruſt on their ſupports. The beams are alſo greatly weakened by the mortiſes which are cut in them to receive the tenons of the croſſing beams: and thus the whole is exceedingly weak, in proportion to what the ſame quantity of timber may be made by a proper diſpoſition of its parts.

3
General principles of conſtruction.

The principles from which we are to derive this diſpoſition are the general mechanical principles of carpentry, of which we have given ſome account in that article. Theſe furniſh one general rule: When we would give the utmoſt ſtrength poſſible to a frame of carpentry, every piece ſhould be ſo diſpoſed that it is ſubject to no ſtrain but what either puſhes or draws it in the direction of its length: and, if we would be indebted to timber alone for the force or ſtrength of the centre, we muſt reſt all on the firſt of theſe ſtrains; for when the ſtraining force tends to *draw* a beam out of its place, it muſt be held there by a mortiſe and tenon, which poſſeſſes but a very trifling force, or by iron ſtraps and bolts. Caſes occur where it may be very difficult to make every ſtrain a thruſt, and the beſt artiſts admit of ties; and indeed where we can admit a tie-beam connecting the two feet of our frame, we need ſeek no better ſecurity. But this may ſometimes be very inconvenient. When it is the arch of a bridge that we are to ſupport, ſuch a tie-beam would totally ſtop the paſſage of ſmall craft up and down the river. It would often be in the water, and thus expoſed to the moſt fatal accidents by freſhes, &c. Interrupted ties, therefore, muſt be employed, whoſe joint or meetings muſt be ſupported by ſomething analogous to the king-poſts of roofs. When this is judiciouſly done, the ſecurity is abundantly good. But great judgment is neceſſary, and a very ſcrupulous attention to the diſpoſition of the pieces. It is by no means an eaſy matter to diſcern whether a beam, which makes a part of our centre is in a ſtate of compreſſion or in a ſtate of extenſion. In ſome works of the moſt eminent carpenters even of this day, we ſee pieces conſidered as ſtruts (and conſiderable dependence had on them in this capacity), while they are certainly performing the office of tie-beams, and ſhould be ſecured accordingly. This was the caſe in the boldeſt centre (we think) that has been executed in Europe, that of the bridge of Orleans, by Mr Hupeau. Yet it is evidently of great conſequence not to be miſtaken in this point; for when we are miſtaken, and the piece is ſtretched which we imagine to be compreſſed, we not only are deprived of ſome

support

ſlide down *their* ſlope, till they touch the blocks on which they are to reſt; ſo that, in laying the archſtones, we are by no means allowed to make the great deduction from their weight juſt now mentioned, and which Mr Couplet preſcribes (Mem. Acad. Sciences, 1729). But there is another cauſe which diminiſhes the preſſure on the centres; each block ſlides down the planks on which it is laid, and preſſes on the block below it, in the direction of the tangent to the arch. This preſſure is tranſmitted through this block, in the ſame direction, to the next, and through it to the third, &c. In this manner it is plain that, as the arch advances, there is a tangential preſſure on the lower archſtones, which diminiſhes their preſſure on the frame, and, if ſufficiently great, might even puſh them away from it. Mr Couplet has given an analyſis of this preſſure, and ſhews, that in a ſemicircular arch of uniform thickneſs none of the arch ſtones below 30° preſs on the frames. But he (without ſaying ſo) calculates on the ſuppoſition that the blocks deſcend along the circumference of this frame in the ſame manner as if it were perfectly ſmooth. As this is far from being the caſe, and as the obſtructions are to the laſt degree various and irregular, it is quite uſeleſs to inſtitute any calculation on the ſubject. A little reflection will convince the reader, that in this caſe the obſtruction ariſing from friction *muſt* be taken into account, and that it *muſt not* be taken into account in eſtimating the preſſure of each ſucceſſive courſe of ſtones as they are laid. It is enough that we ſee that the preſſure of the lower courſes of archſtones on the frame is diminiſhed. Mr Couplet ſays, that the whole preſſure of a ſemicircular arch is but $\frac{4}{9}$ths of its weight; but it is much greater, for the reaſon juſt now given. We have tried, with a well-made wooden model (of which the circumference was rubbed with black lead to render it more ſlippery), whether *any* part of the wooden blocks repreſenting the archſtones were detached from the frame by the tangential preſſure of the ſuperior blocks; but we could not ſay confidently that any were ſo detached. We perceived that all kept hold of a thin ſlip of Chineſe paper (alſo rubbed with black lead) between them and the frame, ſo that a ſenſible force was required to pull it out. From a combination of circumſtances, which would be tedious to relate, we believe that the centres carry more than two-thirds of the weight of the arch before the keyſtone is ſet. In elliptical and lower pitched circular arches, the proportion is ſtill greater.

9 By a centre of M. Pitot's.

It ſeems reaſonable enough, therefore, to diſpoſe the framing in the manner propoſed by Pitot, directing the main ſupport to the upper maſs of the arch, which preſſes moſt on the frame. We ſhall derive another advantage from this conſtruction, which has not occurred to Mr Pitot.

There is an evident propriety in the manner in which he has diſtributed the ſupports of the upper part. The ſtruts which carry the king poſt ſpring from thoſe points of the ſtretcher where it reſts on the ſtruts below: thus the ſtretcher, on which all depends, bears no tranſverſe ſtrains. It is ſtretched by the ſtrut above it, and it is compreſſed in a ſmall degree between the ſtruts below it, at leaſt by the outer ones. Mr Pitot propoſes the ſtraining beam GH as a lateral ſupport to the ſtretcher, which may therefore be of two pieces: but although it *does* augment its ſtrength, it does not ſeem neceſſary for it. The ſtretcher is abundantly carried by the ſtrap, which may and ſhould ſuſpend it from the king poſt. The great uſe of the ſtraining piece is to give a firm abutment to the inner ſtruts, without allowing any lateral ſtrain on the ſtretcher. *N. B.* Great care muſt be taken to make the hold ſufficiently firm and extenſive between the ſtretcher and the upper ſtruts, ſo that its coheſion to reſiſt the thruſts from theſe ſtruts may be much employed.

The only imperfection that we find in this frame is the lateral ſtrains which are brought upon the upper ſtruts by the bridles, which certainly tranſmit to them part of the weight of the archſtones on the curves. The ſpace between the curves and ML ſhould alſo have been truſſed. Mr Pitot's form is, however, extremely ſtiff; and the cauſing the middle bridle to reach down to the ſtretcher, ſeems to ſecure the upper ſtruts from all riſk of bending.

This centre gives a very diſtinct view of the offices of all the parts, and makes therefore a proper introduction to the general ſubject. It is the ſimpleſt that can be in its principle, becauſe all the eſſential parts are ſubjected to one kind of ſtrain. The ſtretcher LL is the only exception, and its extenſion is rather a collateral circumſtance than a ſtep in the general ſupport.

10 The ſtrength this fram

The examination of the ſtrength of the frame is extremely eaſy. Mr Pitot gives it for an arch of 60 feet ſpan, and ſuppoſes the archſtones 7 feet long, which is a monſtrous thickneſs for ſo ſmall an arch; 4 feet is an abundant allowance, but we ſhall abide by his conſtruction. He gives the following ſcantlings of the parts:

The ring or circumference conſiſts of pieces of oak 12 inches broad and 6 thick.
The ſtretcher LL is 12 inches ſquare.
The ſtraining piece GH is alſo 12 by 12.
The lower ſtruts 10 by 8.
The king poſt 12 by 12.
The upper ſtruts 10 by 6.
The bridles 20 by 8.

Theſe dimenſions are French, which is about $\frac{1}{17}$th larger than ours, and the ſuperficial dimenſions (by which the ſection and the abſolute ſtrength is meaſured) is almoſt $\frac{1}{8}$th larger than ours. The cubic foot, by which the ſtones are meaſured, exceeds ours nearly $\frac{1}{5}$th. The pound is deficient about $\frac{1}{13}$th. But ſince very nice calculation is neither eaſy nor neceſſary on this ſubject, it is needleſs to depart from the French meaſures, which would occaſion many fractional parts and a troubleſome reduction.

The arch is ſuppoſed to be built of ſtone which weighed 160 pounds per foot. Mr Pitot, by a computation (in which he has committed a miſtake), ſays, that only $\frac{11}{14}$ths of this weight is carried by the frame. We believe, however, that this is nearer the truth than Mr Couplet's aſſumption of $\frac{4}{9}$ths already mentioned.

Mr Pitot farther aſſumes, that a ſquare inch of ſound oak will carry 8640 pounds. By his language we ſhould imagine that it will not carry much more: but this is very far below the ſtrength of any Britiſh oak that we have tried; ſo far, indeed, that we rather imagine that he means that this load may be laid on it with perfect ſecurity for any time. But to compenſate for knots and other accidental imperfections, he aſſumes 7200 as the meaſure of its abſolute force.

He computes the load on each frame to be 707520 pounds, which he reduces to $\frac{11}{14}$ths, or 555908 pounds.

The abſolute force of each of the lower ſtruts is 576000 (at 7200 per inch), and that of the curves 518400. Mr Pitot, conſidering that the curves are kept from bending outwards by the arch ſtones which preſs on them, thinks that they may be conſidered as acting preciſely as the outer ſtruts EI. We have no objection to this ſuppoſition.

11 Computed.

With theſe data we may compute the load which the lower truſs can ſafely bear by the rule delivered in the article Carpentry. We therefore proceed as follows:

Meaſure off by a ſcale of equal parts as, at, each 576000, and add tv 518400. Complete the parallelogram $avxs$, and draw the vertical xc, meeting the horizontal line aC in c. Make cb equal to ca. Join xb, and complete the parallelogram $axby$. It is evident that the diagonal xy will repreſent the load which theſe pieces can carry; for the line av is the united force of the curve AP and the ſtrut IE, and as is the ſtrength of IG. Theſe two are equivalent to ax. xb is, in like manner, equivalent to the ſupport on the other ſide, and xy is the load which will juſt balance the two ſupports ax and bx.

When xy is meaſured on the ſame ſcale, it will be found = 2850000 pounds. This is more than five times the load which actually lies on the frame. It is therefore vaſtly ſtronger than is neceſſary. Half of each of the linear dimenſions would have been quite ſufficient, and the ſtruts needed only to be 5 inches by 4. Even this would have carried twice the weight, and would have borne the load really laid on it with perfect ſafety.

We proceed to meaſure the ſtrength of the upper part. The force of each ſtrut is 432000, and that of the curve is 518400; therefore, having drawn Mv parallel to the ſtrut ON, make Mv = 432000, and Ms = 432000 + 518400. Complete the parallelogram Msrv. Draw the horizontal line rk, cutting the vertical MC in k, and make ky = Mk. It is plain, from what was done for the lower part, that My will meaſure the load which can be carried by the upper part. This will be found = 1160000. This is alſo greatly ſuperior to the load; but not in ſo great a proportion as the other part. The chief part of the load lies on the upper part; but the chief reaſon of the difference is the greater obliquity of the upper ſtruts. This ſhortens the diagonal My of the parallelogram of forces. Mr Pitot ſhould have adverted to this; and inſtead of making the upper ſtruts more ſlender than the lower, he ſhould have made them ſtouter.

The ſtrain on the ſtretcher LL is not calculated. It is meaſured by $r'k'$, when My is the load actually lying on the upper part. Leſs than the ſixth part of the coheſion of the ſtretcher is more than ſufficient for the horizontal thruſt; and there is no difficulty of making the foot joints of the ſtruts abundantly ſtrong for the purpoſe.

The reader will perceive that the computation juſt now given does not ſtate the proportions of the ſtrains *actually exerted* on the different pieces, but the load on the whole, on the ſuppoſition that each piece is ſubjected to a ſtrain proportioned to its ſtrength. The other calculation is much more complicated, but is not neceſſary here.

This centre has a very palpable defect. If the piers ſhould yield to the load, and the feet of the centre fly out, the lower part will exert a very conſiderable ſtrain on the ſtretcher, tending to break it acroſs between N and L, and on the other ſide. HKF of the lower part is firmly bound together, and cannot change its ſhape, and will therefore act like a lever, turning round the point F. It will draw the ſtrut HK away from its abutment with GH, and the ſtretcher will be ſtrained acroſs at the place between H and F, where it is bolted with the bridle. This may be reſiſted in ſome degree by an iron ſtrap uniting ON and HK; but there will ſtill be a want of proportional ſtrength. Indeed, in an arch of ſuch height (a ſemicircle), there is but little riſk of this yielding of the piers; but it is an imperfection.

12 A centre on the ſame principles for an elliptical arch.

The centre (fig. 2.) is conſtructed on the ſame principle preciſely for an elliptical arch (A). The calculation of its ſtrength is nearly the ſame alſo; only the two upper ſtruts of a ſide being parallel, the parallelogram Msrv (of fig. 1.) is not needed, and in its ſtead we meaſure off on ON a line to repreſent twice its ſtrength. This comes in place of Mr' of fig. 1.—*N. B.* The calculation proceeds on the ſuppoſition that the ſhort ſtraining piece MM makes but one firm body with the king poſt. Mr Pitot employed this piece (we preſume) to ſeparate the heads of the ſtruts, that their obliquity might be leſſened thereby: and this is a good thought; for when the angle formed by the ſtruts on each ſide is very open, the ſtrain on them becomes very great.

The ſtretcher of this frame is ſcarfed in the middle. Suppoſe this joint to yield a little, there is a danger of the lower ſtrut ON loſing its hold, and ceaſing to join in the ſupport; for when the crown ſinks by the lengthening of the ſtretcher, the triangle ORN of fig. 2. will be more diſtorted than the ſpace above it, and ON will be looſened. But this will not be the caſe when the ſinking of the crown ariſes from the mere compreſſion of the ſtruts. Nor will it happen at all in the centre, fig. 1. On the contrary, the ſtrut ON will abut more firmly by the yielding of the foot of ML.

The figure of this arch of Mr Pitot's conſiſts of three arches of circles, each of 60 degrees. As it is elegant, it will not be unacceptable to the artiſt to have a conſtruction for this purpoſe.

13 How to conſtruct ſuch an arch.

Make BY = CD, and CZ = $\frac{1}{2}$ CY. Deſcribe the ſemicircle ZÆY, and make ZS = ZÆ. S is the centre of the ſide arches, each of 60 degrees. The centre T of the arch, which unites theſe two, is at the angle of an equilateral triangle STS.

This conſtruction of Mr Pitot's makes a handſome oval, and very near an ellipſis, but lies a little without it. We ſhall add another of our own, which coincides with the ellipſe in eight points, and furniſhes the artiſt, by

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(A) It is the middle arch of the bridge at Lille Adam, of which Mr Pitot had the direction. It is of 80 feet ſpan, and riſes 31 feet.

by the way, a rule for drawing an infinite variety of ovals.

Let AB, DE (fig. 2. N° 2.) be the axes of an ellipſe, C the centre, and F, *f* the two foci. Make $Cb = CD$, and deſcribe a circle $ADbe$ paſſing through the three given points A, D, and *b*. It may be demonſtrated, that if from any point P of the arch AD be drawn a chord PD, and if a line PRr be drawn, making the angle $DPR = PDC$, and meeting the two axes in the points R and *r*, then R and *r* will be the centres of circles, which will form a quarter APD of an oval, which has AB and DE for its two axes.

We want an oval which ſhall coincide as much as poſſible with an ellipſis? The moſt likely method for this is to find the very point P where the ellipſis cuts the circle $ADbe$. The eaſieſt way for the artiſt is to deſcribe an arch of a circle *a m*, having AB for its radius, and the remote focus *f* for its centre. Then ſet one foot of the compaſſes on any point P, and try whether the diſtance PF from the neareſt focus F is exactly equal to its diſtance Pm from that circle. Shifting the foot of the compaſſes from one point of the arch to another, will ſoon diſcover the point. This being found, draw PD, make the angle $DPr = PDr$, and R and *r* are the centres wanted. Then make $Cſ = CR$, and we get the centres for the other ſide.

The geometer will not reliſh this mechanical conſtruction. He may therefore proceed as follows: Draw Dd parallel to AB, cutting the circle in *d*. Draw *e d*, cutting AC in N. Draw CG parallel to Ae, and make the angle $CGi = ADe$. Biſect CN in O, and join Oi. Make OM, $OM' = Oi$, and draw MP, M′P′ perpendicular to AB. Theſe ordinates will cut the circle $ADbe$ in the points P and P′, where it is cut by the ellipſe. We leave the demonſtration as a geometrical exerciſe for the dilettante.

14
Centre for the nave of St Peter's.

We ſaid, that this centering of Mr Pitot's reſembled in principle the one employed by Michael Angelo for the nave and tranſepts of St Peter's church at Rome. Fontana, who has preſerved this, aſcribes the conſtruction of it to one of the name of San Gallo. A ſketch of it is given in fig. 3. It is, however, ſo much ſuperior, and ſo different in principle, from that employed for the cupola, that we cannot think it the invention of the ſame perſon. It is, like Pitot's, not only diviſible, but really divided into two parts, of which the upper carries by much the greateſt part of the load. The pieces are judiciouſly diſpoſed, and every important beam is amply ſecured againſt all tranſverſe ſtrains. Its only fault is a great profuſion of ſtrength. The innermoſt polygon *a g h b* is quite ſuperfluous, becauſe no ſtrain can force in the ſtruts which reſt on the angles. Should the piers yield outwards, this polygon will be looſe, and can do no ſervice. Nor is the triangle *g i h* of any uſe, if the king poſt above it be ſtrapped to the tie-beam and ſtraining ſill. Perhaps the inventor conſidered the king poſt as a pillar, and wiſhed to ſecure the tie-beam againſt its croſs ſtrain. This centering, however, muſt be allowed to be very well compoſed; and we expect that the well informed reader will join us in preferring it to Mr Pitot's, both for ſimplicity of principle, for ſcientific propriety, and for ſtrength.

There is one conſiderable advantage which may be derived from the actual diviſion of the truſs into two parts. If the tie-beam LL, inſtead of reſting on the ſtretcher EF, had reſted on a row of chocks formed like double wedges, placed above each other, head to point, the upper part of the centering might be ſtruck independent of the lower, and this might be done gradually, beginning at the outer ends of the ſtretcher. By this procedure, the joints of the archſtones will cloſe on the haunches, and will almoſt relieve the lower centering, ſo that all can be pulled out together. Thus may the arch ſettle and conſolidate in perfect ſafety, without any chance of breaking the bond of the mortar in any part; an accident which frequently happens in great arches. This procedure is peculiarly adviſable for low pitched or elliptical arches. But this will be more clearly ſeen afterwards, when we treat of the internal movements of an arch of maſonry.

This may ſuffice for an account of the more ſimple conſtruction of truſſed centres; and we proceed to ſuch as have a much greater complication of principle. We ſhall take for examples ſome conſtructed by Mr Perronet, a very celebrated French architect.

15
Perronet's maxim of conſtruction.

Mr Perronet's general maxim of conſtruction is to make the truſs conſiſt of ſeveral courſes of ſeparate truſſes, independent (as he thinks) of each other, and thus to employ the joint ſupport of them all. In this conſtruction it is not intended to make uſe of one truſs, or part of one truſs, to ſupport another, as in the former ſet, and as is practiſed in the roofs of St Paul's church, Covent Garden, and in Drury Lane theatre. Each truſs ſpans over the whole diſtance of the piers, and would ſtand alone (having, however, a tottering equilibrium). It conſiſts of a number of ſtruts, ſet end to end, and forming a polygon. Theſe truſſes are ſo arranged, that the angles of one are in the middle of the ſides of the next, as when a polygon is inſcribed in a circle, and another (of the ſame number of ſides) is circumſcribed by lines which touch the circle in the angles of the inſcribed polygon. By this conſtruction the angles of the alternate truſſes lie in lines pointing towards the centre of the curve. King poſts are therefore placed in this direction between the adjoining beams of the truſſes. Theſe king poſts conſiſt of two beams, one on each ſide of the truſs, and embrace the truſs-beams between them, meeting in the middle of their thickneſs. The abutting beams are mortiſed, half into each half of the poſt. The other beam which makes the baſe of the triangle, paſſes through the poſt, and a ſtrong bolt is driven through the joint, and ſecured by a key or a nut. In this manner is the whole united; and it is expected, that when the load is laid on the uppermoſt truſs, it will all butt together, forcing down the king poſts, and therefore preſſing them on the beams of all the inferior truſſes, cauſing them alſo to abutt on each other, and thus bear a ſhare of the load. Mr Perronet does not aſſume the invention to himſelf; but ſays, that it was invented and practiſed by Mr Manſard de Sagonne at the great bridge of Moulins. It is much more ancient, and is the work of the celebrated phyſician and architect Perrault; as may be ſeen in the collection of machines and inventions of that gentleman publiſhed after his death, and alſo in the great collection of inventions approved of by the Academy of Sciences. It is this which we propoſe to examine.

16
Centering employed for the bridge of Cravant,

Fig. 4. repreſents the centering employed for the bridge of Cravant. The arches are elliptical, of 60 feet ſpan and 20 feet riſe. The archſtones are four feet thick, and weigh 176 pounds per foot. The truſs-beams were from 15 to 18 feet long, and their ſection was 9 inches by 8. Each half of the king poſts was about 7 feet long, and its ſection 9 inches by 8. The whole was of oak. The five truſſes were $5\frac{1}{2}$ feet aſunder. The whole weight of the arch was 1350000 lbs. which we may call 600 tons (it is 558). This is about 112 tons for each truſs. We muſt allow near 90 tons of this really to preſs the truſs. A great part of this preſſure is borne by the four beams which make the feet of the truſs, coupled in pairs on each ſide. The diagonal of the parallelogram of forces drawn for theſe beams is, to one of the ſides, in the proportion of 360 to 285. Therefore ſay, as 360 to 285; ſo is 90 to $71\frac{1}{4}$ tons, the thruſt on each foot. The ſection of each is 144 inches. We may with the utmoſt ſafety lay three tons on every inch for ever. This amounts to 432 tons, which is more than ſix times the ſtrain really preſſing the foot beams in the direction of their length; nay, the upper truſs alone is able to carry much more than its load. The abſolute ſtrength of its foot-beam is 216 tons. It is much more advantageouſly placed; for the diagonal of the parallelogram of forces correſponding to its poſition is to the ſide as 438 to 285. This gives $58\frac{6}{10}$ tons for the ſtrain on each foot; which is not much above the fourth part of what it is able to carry for ever. No doubt can therefore be entertained of the ſuperabundant ſtrength of this centering. We ſee that the upper row of ſtruts is quite ſufficient, and all that is wanted is to procure ſtiffneſs for it; for it muſt be carefully kept in mind, that this upper row is not like an equilibrated arch. It will be very unequally loaded as the work advances. The haunches of the frame will be preſſed down, and the joints at the crown raiſed up. This muſt be reſiſted.

Here then we may gather, by the way, a uſeful leſſon. Let the outer row of ſtruts be appropriated to the carriage of the load, and let the reſt be employed for giving ſtiffneſs. For this purpoſe let the outer row have abundant ſtrength. The advantages of this method are conſiderable. The poſition of the beams of the exterior row is more advantageous, when (as in this example) the whole is made to reſt on a narrow foot: for this obliges us to make the laſt angle, at leaſt of the lower row, more open, which increaſes the ſtrain on the ſtrut; beſides, it is next to impoſſible to diſtribute the compreſſing thruſts among the different rows of the truſs-beams; and a beam which, during one period of the maſon work, is acting the part of a ſtrut, in another period is bearing no ſtrain but its own weight, and in another it is ſtretched as a tie. A third advantage is, that, in a caſe like this, where all reſts on a narrow foot, and the lower row of beams are bearing a great part of the thruſt, the horizontal thruſt on the pier is very great, and may puſh it aſide. This is the moſt ruinous accident that can happen. An inch or two of yielding will cauſe the crown of the arch to ſink prodigiouſly, and will inſtantly derange all the bearings of the abutting beams: but when the lower beams already act as ties, and are quite adequate to their office, we render the frame perfectly ſtiff or unchangeable in its form, and take away the horizontal thruſt from the piers *entirely*. This advantage is the more valuable, becauſe the very circumſtance which obliges us to reſt all on a narrow foot, places this foot on the very top of the pier, and makes the horizontal thruſt the more dangerous.

But, to proceed in our examination of the centering of Cravant bridge, let us ſuppoſe, that the king poſts are removed, and that the beams are joined by compaſs joints. If the pier ſhall yield in the ſmalleſt degree, both rows of ſtruts muſt ſink; and ſince the angles (at leaſt the outermoſt) of the lower row are more open than thoſe of the upper row, the crown of the lower row will ſink more than that of the upper.

The angles of the alternate rows muſt therefore ſeparate a little. Now reſtore the king poſts; they prevent this ſeparation. Therefore *they are ſtretched;* therefore the beams of the lower row are alſo ſtretched; conſequently they no longer butt on their mortiſes, and muſt be held in their places by bolts. Thus it appears that, in this kind of ſagging, the original diſtribution of the load among the different rows of beams is changed, and the upper row becomes loaded beyond our expectation.

If the ſagging of the whole truſs proceed only from the compreſſion of the timbers, the caſe is different, and we *may* preſerve the original diſtribution of mutual abutment more accurately. But in this caſe the ſtiffneſs of the frame ariſes chiefly from croſs ſtrains. Suppoſe that the frame is loaded with archſtones on each ſide up to the poſts HC, *hc*; the angles E and *e* are preſſed down, and the beams EOF, *eo* F puſh up the point F. This cannot riſe without bending the beams EOF, *eo* F; becauſe O and *o* are held down by the double king poſts, which graſp the beams between them. There is therefore a croſs ſtrain on the beams. Obſerve alſo, that the triangle EHF does not preſerve its ſhape by the connection of its joints; for although the ſtrut beams are mortiſed into the king poſt, they are in very ſhallow mortiſes, rather for ſteadying them than for holding them together. Mr Perronet did not even pin them, thinking that their abutment was very great. The triangle is kept in ſhape by the baſe EF, which is firmly bolted into the middle poſt at O. Had theſe interſections not been ſtrongly bolted, we imagine that the centres of ſome of Mr Perronet's bridges would have yielded much more than they did; yet ſome of them yielded to a degree that our artiſts would have thought very dangerous. Mr Perronet was obliged to load the crown of the centering with very great weights, increaſing them as the work advanced, to prevent the frames from going out of ſhape: in one arch of 120 feet he laid on 45 tons. Notwithſtanding this imperfection, which is perhaps unavoidable, this mode of framing is undoubtedly very judicious, and perhaps the beſt which can be employed without depending on iron work.

17 For the bridge of Nogent,

Fig. 5. repreſents another, conſtructed by Perronet for an arch of 90 feet ſpan and 28 feet riſe. The truſſes were 7 feet apart, and the arch was $4\frac{1}{2}$ thick; ſo that the unreduced load on each frame was very nearly 235 tons. The ſcantling of the ſtruts was 15 by 12 inches. The principle is the ſame as that of the former. The chief difference is, that in this centre the outer truſs-beam of the lower row is not coupled with the middle row, but kept nearly parallel to the outer beam of the upper row. This adds greatly to the ſtrength of the foot, and takes off much of the horizontal thruſt from the pier.

Mr Perronet has ſhewn great judgment in cauſing the polygon of the inner row of truſs-beams gradually to approach the polygon of the outer row. By this diſpoſition, the angles of the inner polygon are more acute than thoſe of the outer. A little attention will ſhew, that the general ſagging of all the polygons will keep the abutments of the lower one nearer, or exactly, to their original quantity. We muſt indeed except the foot-beam. It is ſtill too oblique; and, inſtead of converging to the foot of the upper row, it ſhould have diverged from it. Had this been done, this centre is almoſt perfect in its kind. As it is, it is at leaſt ſix times ſtronger than was abſolutely neceſſary. We ſhall have occaſion to refer to this figure on another occaſion.

18 St Maxence

This maxim is better exemplified by Mr Perronet in the centering of the bridge of St Maxence, exhibited in fig. 5. n° 2. than in that of Nogent, fig. 5. n° 1. But we think that a horizontal truſs-beam *a b* ſhould have been inſerted (in a ſubordinate manner) between the king poſts next the crown on each ſide. This would prevent the crown from riſing while the haunches only are loaded, without impairing the fine abutments of *c d*, *c d*, when the arch is nearly completed. This is an excellent centering, but is not likely to be of much uſe in theſe kingdoms; becauſe the arch itſelf will be conſidered as ungraceful and ugly, looking like a huge lintel. Perronet ſays, that he preferred it to the ellipſe, becauſe it was lighter on the piers, which were thin. But the failure of one arch muſt be immediately followed by the ruin of all. We know much better methods of lightening the piers.

19 Neuilly, and

Fig. 6. repreſents the centering of the bridge of Neuilly, near Paris, alſo by Perronet. The arch has 120 feet ſpan, and 30 feet riſe, and is 5 feet thick. The frames are 6 feet apart, and each carries an abſolute (that is, not reduced to $\frac{11}{14}$ or to $\frac{4}{9}$) load of 350 tons. The ſtrut beams are 17 by 14 inches in ſcantling. The king poſts are of 15 by 9 each half; and the horizontal bridles which bind the different frames together in five places, are alſo 15 by 9 each half. There are eight other horizontal binders of 9 inches ſquare.

This is one of the moſt remarkable arches in the world; not altogether on account of its width (for there are ſeveral much wider), but for the flatneſs at the crown; for about 26 feet on each ſide of the middle it was intended to be a portion of a circle of 150 feet radius. An arch (ſemicircular) of 300 feet ſpan might therefore be eaſily conſtructed, and would be much ſtronger than this, becauſe its horizontal thruſt at the crown would be vaſtly greater, and would keep it more firmly united.

The bolts of this centre are differently placed from thoſe of the former; and the change is judicious. Mr Perronet had doubtleſs found by this time, that the ſtiffneſs of his framing depended on the tranſverſe ſtrength of the beams; and therefore he was careful not to weaken them by the bolts. But notwithſtanding all his care, the framing ſunk upwards of 13 inches before the keyſtones were laid; and during the progreſs of the work, the crown roſe and ſunk, by various ſteps, as the loading was extended along it. When 20 courſes were laid on each ſide, and about 16 tons laid on the crown of each frame, it ſunk about an inch. When 46 courſes were laid, and the crown loaded with 50 tons, it ſunk about half an inch more. It continued ſinking as the work advanced; and when the keyſtone was ſet it had ſunk $13\frac{1}{4}$ inches. But this ſinking was not general; on the contrary the frame had riſen greatly at the very haunches, ſo as to open the upper part of the joints, many of which gaped an inch; and this opening of the joints gradually extended from the haunches towards the crown, in the neighbourhood of which they opened on the under ſide. This evidently aroſe from a want of ſtiffneſs in the frame. But theſe joints cloſed again when the centres were ſtruck, as will be mentioned afterwards.

We have taken particular notice of the movements and twiſting of this centre, becauſe we think that they indicate a deficiency, not only of ſtiffneſs, but of abutment among the truſs beams. The whole has been too flexible, becauſe the angles are too obtuſe: This ariſes from their multiplicity. When the intercepted arches have ſo little curvature, the power of the load to preſs it inward increaſes very faſt. When the intercepted arch is reduced to one half, this power is more than doubled; and it is alſo doubled when the radius of curvature is doubled. The king-poſts ſhould have been further apart near the crown, ſo that the quantity of arch between them ſhould compenſate for its diminiſhed curvature.

The power of withſtanding any given ineqnality of load would therefore have been greater, had the centre conſiſted of fewer pieces, and their angles of meeting been proportionally more acute. The greateſt improvement would have been, to place the foot of the lower tier of truſs-beams on the very foot of the pier, and to have alſo ſeparated it at the head from the reſt with a longer king-poſt, and thus to have made the diſtances of the beams on the king-poſts increaſe gradually from the crown to the ſpring. This would have made all the angles of abutment more acute, and would have produced a greater preſſure on all the lower tiers when the frame ſagged.

20 Orleans.

Fig. 7. repreſents the centering of the bridge of Orleans. The arch has 100 feet ſpan, and riſes 30, and the archſtones are 6 feet long. It is the conſtruction of Mr Hupeau, the firſt architect of the bridge. It is the boldeſt work of the kind that we have ſeen, and is conſtructed on clear principles. The main abutments are few in number. Becauſe the beams of the outer polygon are long, they are very well ſupported by ſtraining beams in the middle; and the ſtruts or braces which ſupport and butt on them, are made to reſt on points carried entirely by *ties*. The inventor, however, ſeems to have thought that the angles of the inner polygon were ſupported by mutual compreſſion, as in the outer polygon. But it is plain that the whole inner polygon may be formed of iron rods. Not but that both polygons *may* be in a ſtate of compreſſion (this is very poſſible); but the ſmalleſt ſagging of the frame will change the proportions of the preſſures at the angles of the two polygons. The preſſures on the exterior angles will increaſe, and thoſe on the lower or interior angles will diminiſh moſt rapidly; ſo that the abutments in the lower polygon will be next to nothing. Such points could bear very little preſſure from the braces which ſupport the middle of the long bearings of the upper beams, and their preſſures muſt be borne chiefly by the joints ſupported by the king-poſts. The king-poſts would then be in a ſtate of extenſion. It is difficult, however, to decide what is the preciſe ſtate of the preſſure at theſe interior angles.

CENTRES. Plate XIV.

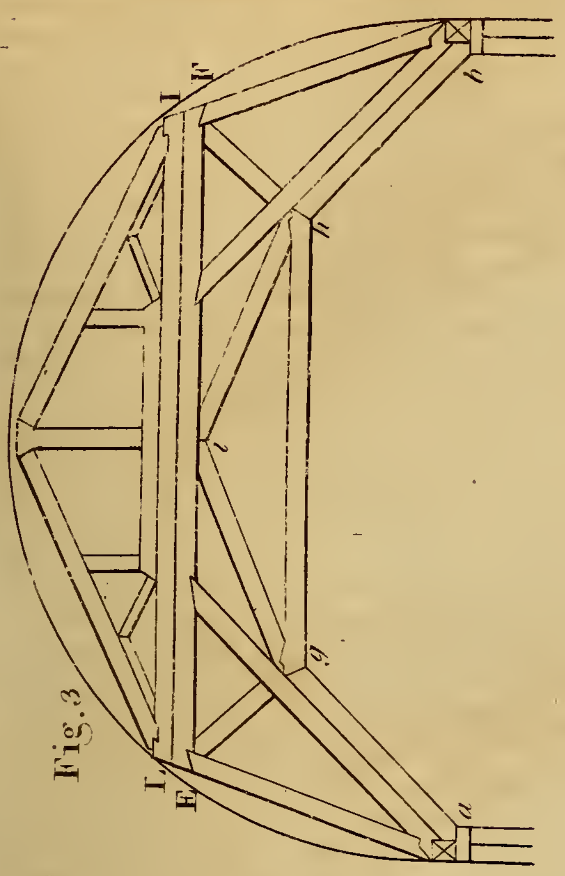


Fig. 3

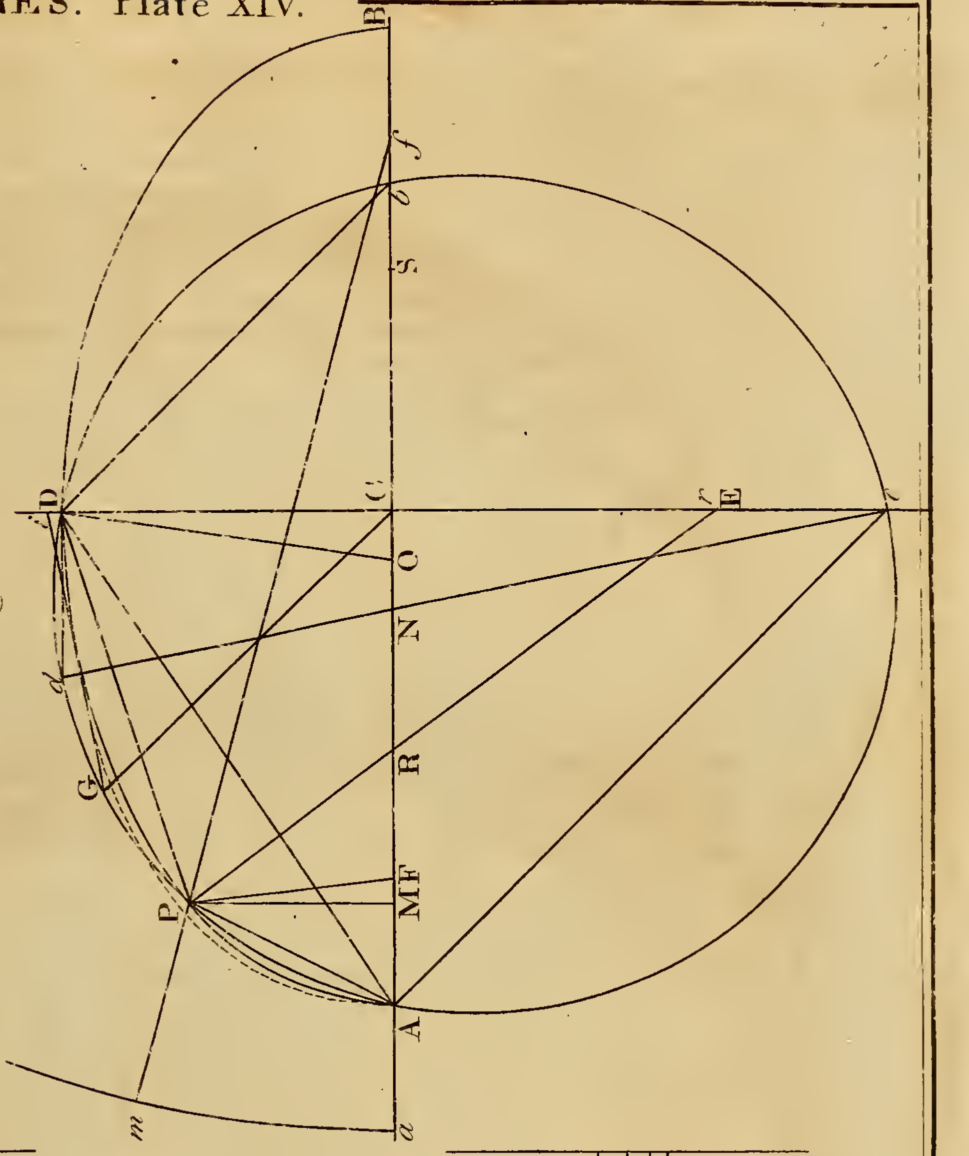


Fig. 2. No. 2.

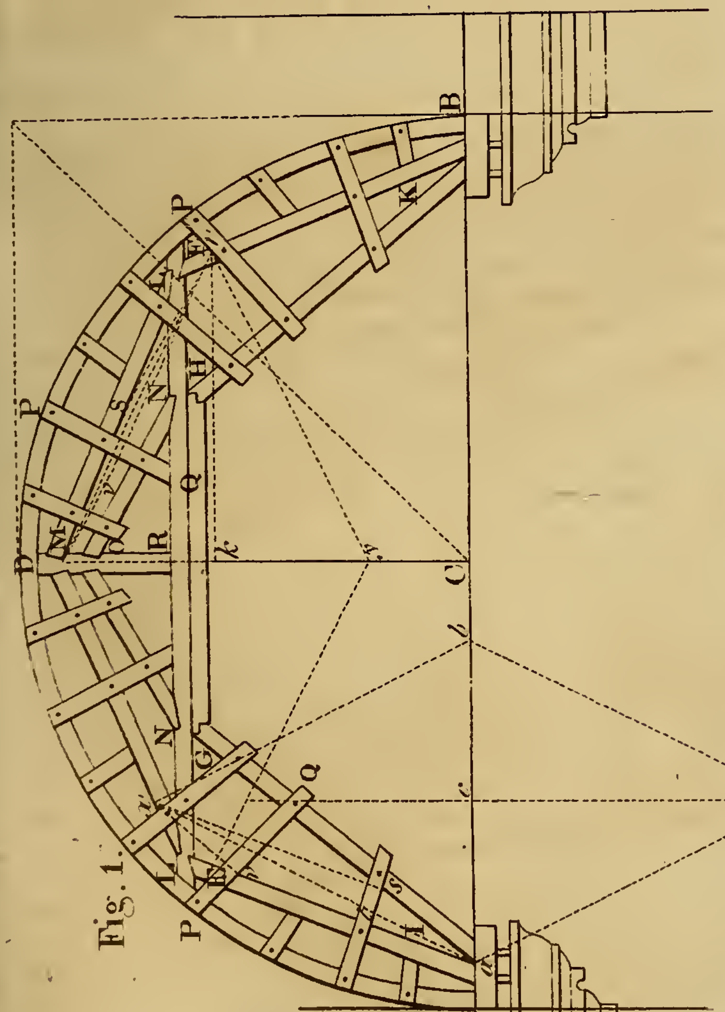


Fig. 1.

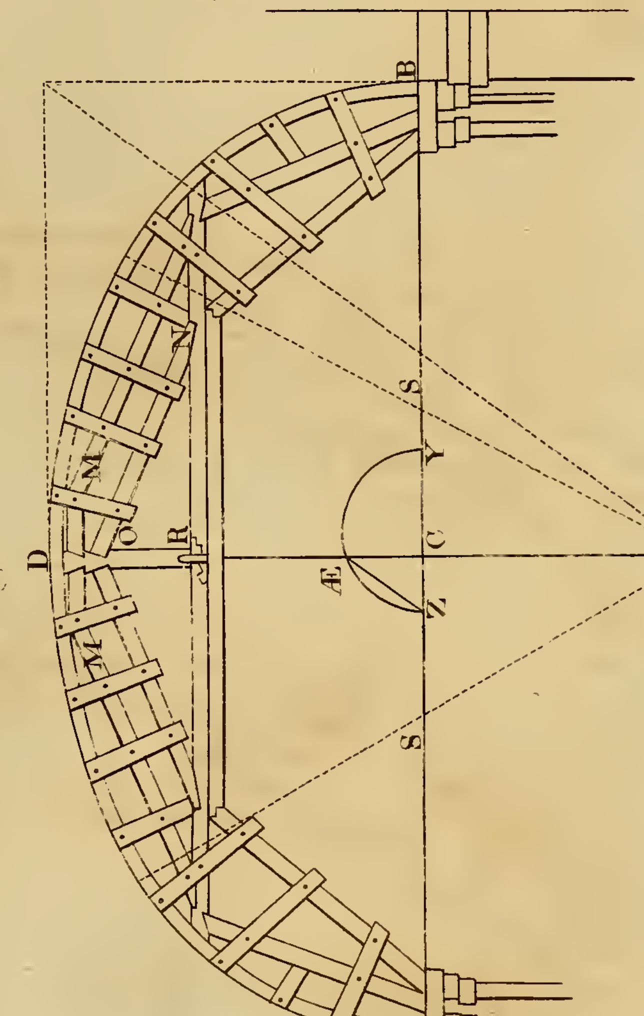
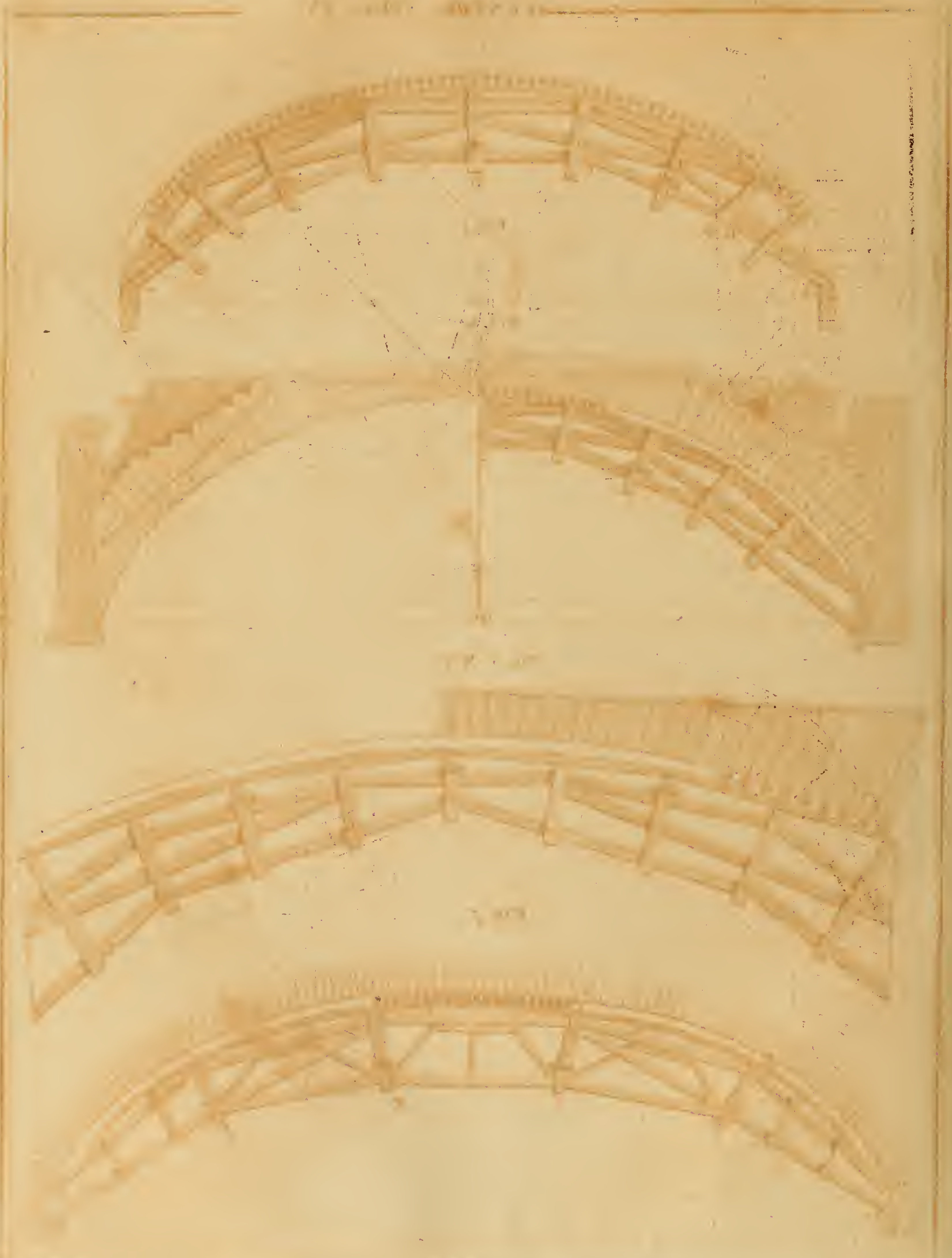


Fig. 2.



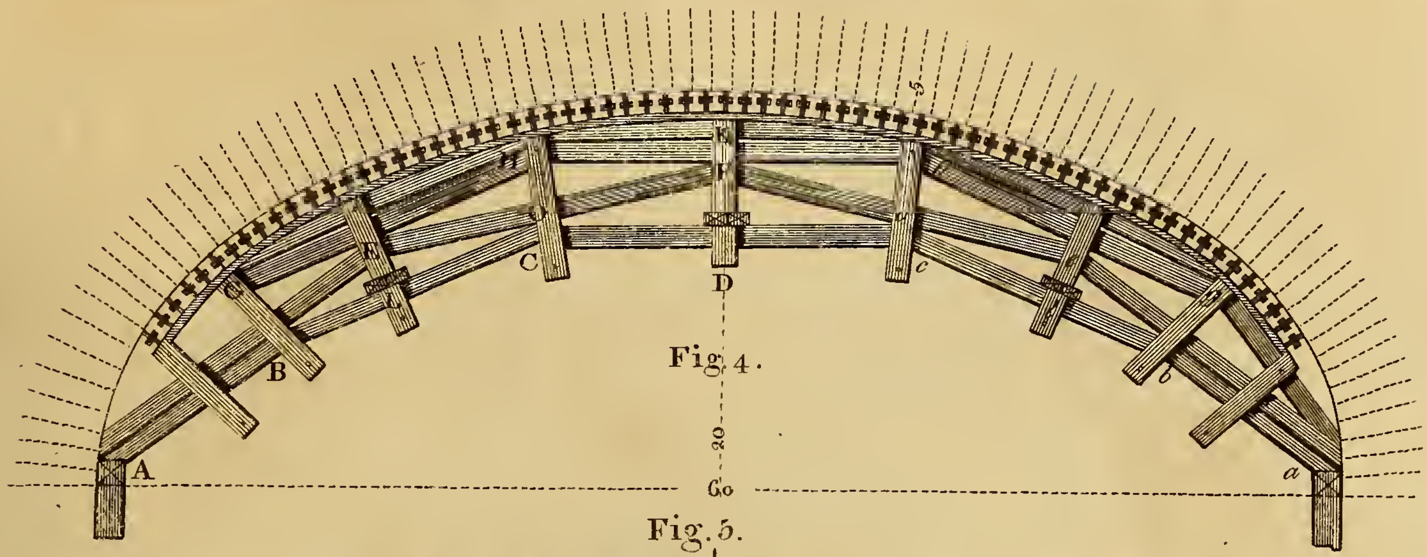


Fig. 4.

Fig. 5.

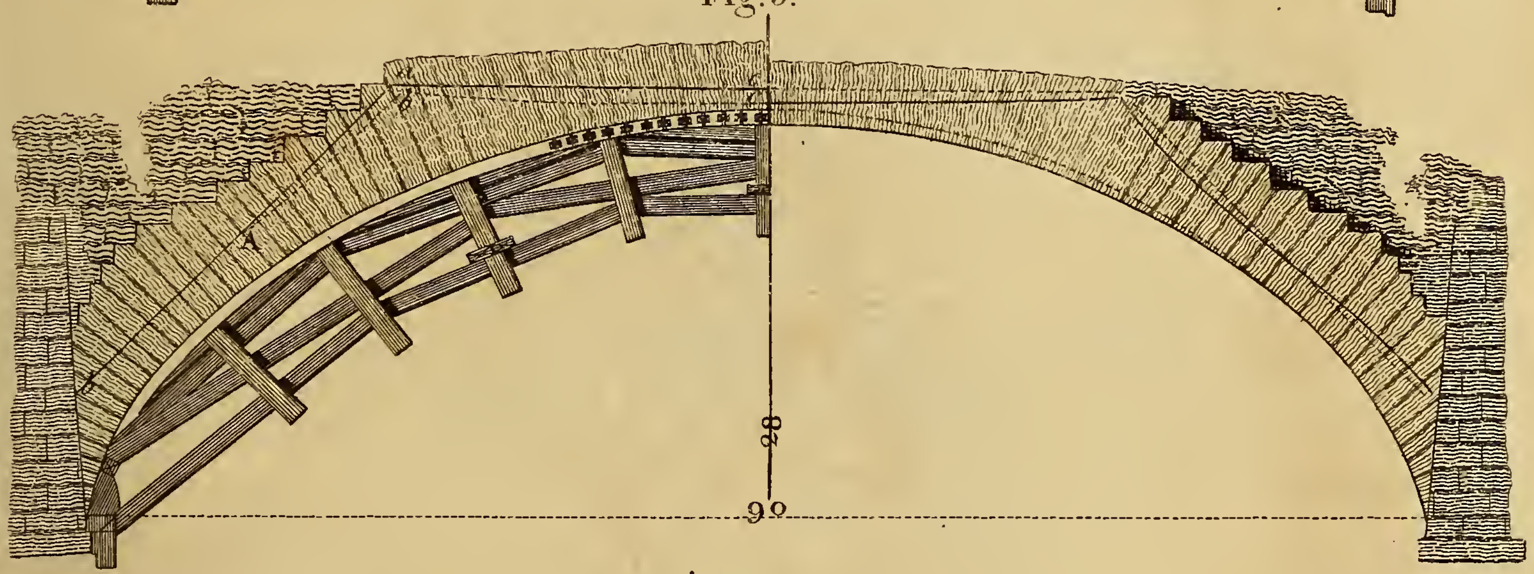


Fig. 5. N°2.

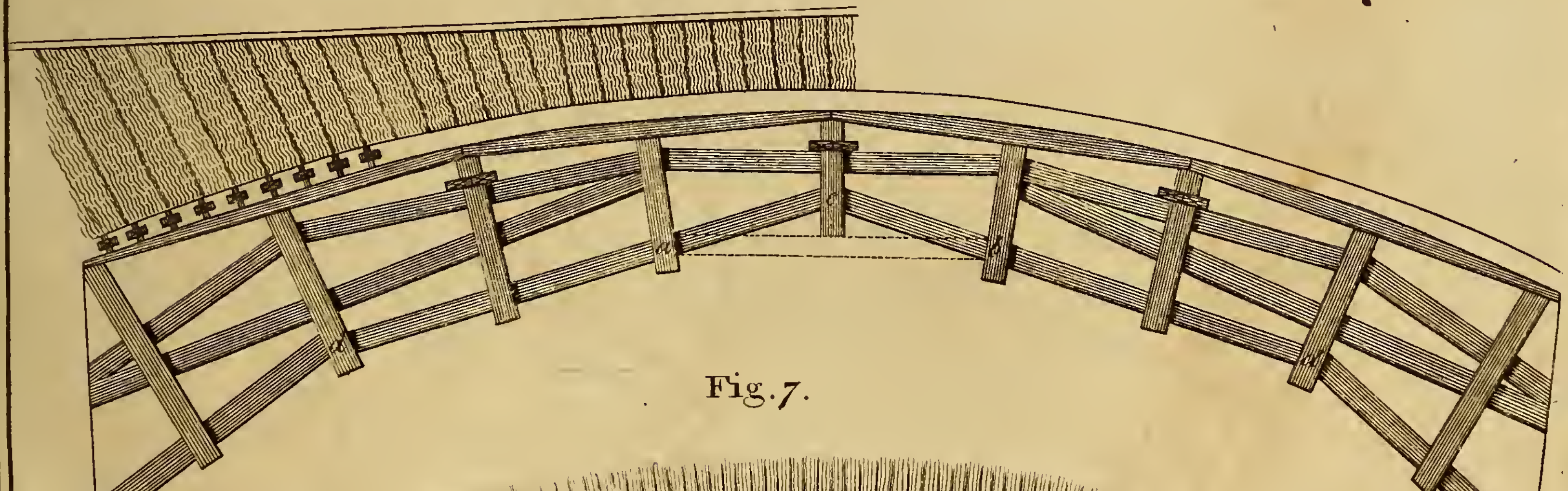
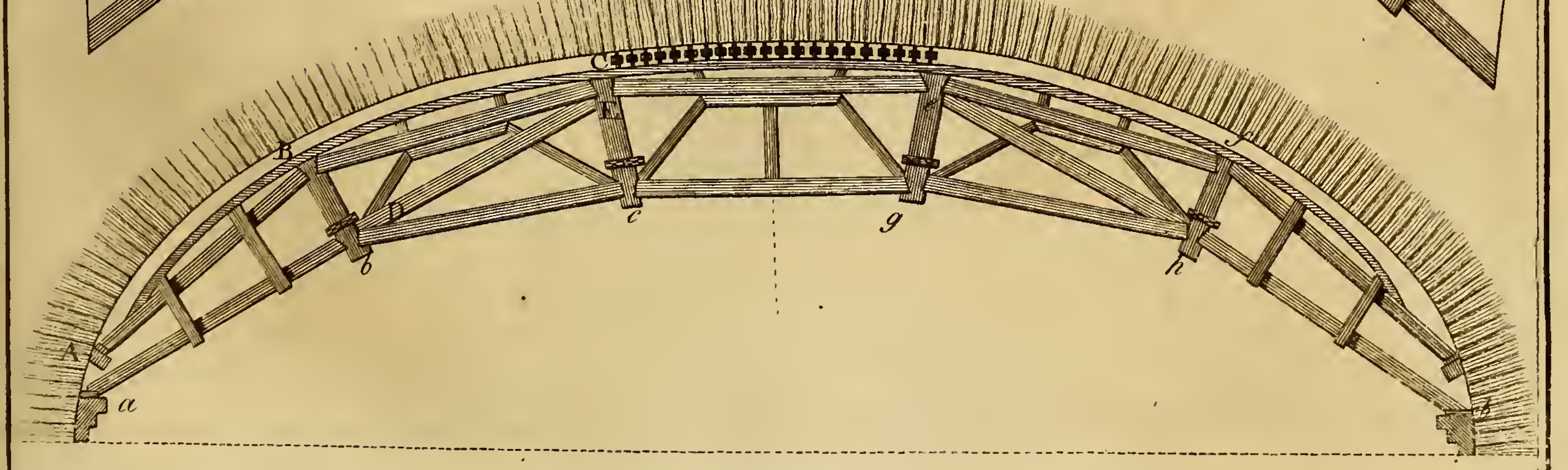


Fig. 7.



R. Scot sc.

though one leg of the truſs is very oblique, the other compenſates for it by its upright poſition.

The chief peculiarity of this centre is to be ſeen in its baſe. This demands a more particular attention; but we muſt firſt make ſome obſervations on the condition of an arch, as it reſts on the centering after the keyſtones are all ſet, and on the gradual transference of the preſſure from the boards of the centering to the joints of the archſtones.

24 Obſervations on the ſtate of an arch as it reſts on the centering.

While all the archſtones lie on the centering, the lower courſes are alſo leaning pretty ſtrongly on each other. But the mortar is hardly compreſſed in the joints; and leaſt of all in the joints near the crown. Suppoſe the arch to be Catenarean, or of any other ſhape that is perfectly equilibrated: When the centering is gradually withdrawn, all the archſtones follow it. Their wedge-like form makes this impoſſible, without the middle ones ſqueezing the lateral ones aſide. This compreſſes the mortar between them. As the ſtones thus come nearer to each other, thoſe near the crown muſt deſcend more than thoſe near the haunches, before every ſtone has leſſened its diſtance from the next by the ſame quantity; for example, by the hundredth part of an inch. This circumſtance alone muſt cauſe a ſinking in the crown, and a change of ſhape. But the joints near the crown are *already* more open than thoſe near the haunches. This produces a ſtill greater change of form before all is ſettled. Some maſons endeavour to remedy, or at leaſt to diminiſh, this, by uſing no mortar in the joints near the crown. They lay the ſtones dry, and even force them together by wedges and blocks laid between the ſtones on oppoſite ſides of the crown: They afterwards pour in fine cement. This appears a good practice. Perronet rejects it, becauſe the wedging ſometimes breaks the ſtones. We ſhould not think this any great harm; becauſe the fracture will make them cloſe where they would otherwiſe lie hollow. But, after all our care, there is ſtill a ſinking of the crown of the arch. By gradually withdrawing the centering, the joints cloſe, the archſtones begin to butt on each other, and to force aſide the lateral courſes. This abutment gradually increaſing, the preſſure on the haunches of the centering is gradually diminiſhed by the mutual abutment, and ceaſes entirely in that courſe, which is the loweſt that formerly preſſed it: it then ceaſes in the courſe above, and then in the third, and ſo on. And, in this manner, not only the centering quits the arch, gradually, from the bottom to the top, *by its own retiring from it*, but the arch alſo quits the centering *by changing its ſhape*. If the centering were now puſhed up again, it would touch the arch firſt at the crown; and it muſt *lift up* that part gradually before it come again in contact with the haunches. It is evident, therefore, that an arch, built on a centre of a ſhape perfectly ſuited to equilibration, will not be in equilibrio when the centering is removed. It is therefore neceſſary to form the centering in ſuch a manner (by raiſing the crown), that it ſhall *leave* the arch of a proper form. This is a very delicate taſk, requiring a previous knowledge of the enſuing change of form. This cannot be aſcertained by the help of any theory we are acquainted with.

But, ſuppoſe this attained, there is another difficulty: While the work advances, the centering is warped by the load laid on it, and continually increaſing on each ſide. The firſt preſſure on the centering forces down the haunches, and raiſes the crown. The arch is therefore leſs curved at the haunches than is intended: the joints, however, accommodate themſelves to this form, and are cloſe, and filled with mortar. When the maſons approach the middle of the arch, the frame ſinks there, and riſes up at the haunches. This opens all the joints in that place on the *upper* ſide. By the time that the keyſtones are ſet, this warping has gone farther; and joints are opened on the *under* ſide near the crown. It is true we are here ſpeaking rather of an extreme caſe, when the centering is *very* flexible; but this occurred to Mr Perronet in the two great bridges of Neuilly and of Mantz. In this laſt one, the crown ſunk above a foot before the key was ſet, and the joints at the haunches opened above an inch *above*, while ſome nearer the crown opened near a quarter of an inch *below*.

25 A delicat buſineſs t ſtrike the centering

In this condition of things, it is a delicate buſineſs to ſtrike the centering. Were it removed in an inſtant, all would probably come down; for the archſtones are not yet abutting on each other, and the joints in the middle are open below. Mr Perronet's method appears to us to be very judicious. He began to detach the centering at the very bottom, on each ſide equally, where the preſſure on the centering is very ſlight. He cut away the blocks which were immediately under each archſtone. He proceeded gradually upwards in this way with ſome ſpeed, till all was detached that had been put out of ſhape by the bending of the centering. This being no longer ſupported, ſunk inward, till it was ſtopped by the abutment which it found on the archſtones near the crown which were ſtill reſting on their blocks. During part of this proceſs, the open joints opened ſtill more, and looked alarming. This was owing to the removal of the load from the haunches of the centering. This allowed the crown to ſink ſtill more, by forcing out the arch ſtones at the haunches. He now pauſed ſome days; and during this time the two haunches, now hanging in the air, gradually preſſed in toward the centering, their outer joints cloſing in the meanwhile. The haunches were now preſſing pretty hard on the arch ſtones nearer the crown. He then proceeded more ſlowly, deſtroying the blocks and bridgings of theſe upper archſtones. As ſoon as he deſtroyed the ſupport of one, it immediately yielded to the preſſure of the haunch; and if the joint between it and the one adjoining toward the crown happened to be open, whether on the under or the upper ſide, it immediately cloſed on it. But in proceeding thus, he found every ſtone ſink a little while it cloſed on its neighbour; and this was like to produce a ragged ſoffet, which is a deformity. He therefore did not allow them to ſink ſo much. In the places of the blocks and bridgings which he had cut away, he ſet ſmall billets, ſtanding on their ends, between the centering and the archſtones. Theſe allowed the pendulous arch to puſh toward the crown without ſenſibly deſcending; for the billets were puſhed out of the perpendicular, and ſome of them tumbled down. Proceeding in this way, he advanced to the very next courſe to the keyſtone on each ſide, the joints cloſing all the way as he advanced. The laſt job was very troubleſome; we mean the detaching the three uppermoſt courſes from the centering: for the whole elaſticity of the centering was now trying to unbend, and preſſing hard againſt them. He found that they were lifted up; for the joints a part of the fortifications more than 300 years old. The mortar between the bricks was harder than the bricks (which were Dutch clinkers, ſuch as are now uſed only for the greateſt loads); but when mixed with water it made it limewater, ſeemingly as ſtrong as if freſh lime had been uſed. We obſerved the ſame thing in one ſmall part of a huge maſs of ancient Roman work near Romney in Kent; but the reſt, and all the *very old* mortar that we have ſeen, was in a mild ſtate, and was generally much harder than what produced any lime water. Now when the mortar in the joints has begun its firſt cryſtallization, and is allowed to remain in perfect reſt, we are confident that the ſubſequent cryſtals, whether of lime, or of calcareous earth, or of gypſum, will be much larger and ſtronger than can ever be produced if they are once broken; and the farther that this cryſtallization has been carried, that is, the harder that the mortar has become, leſs of it remains to take any new cryſtallization. Why ſhould it be otherwiſe here than in every other cryſtallization that we are acquainted with?

28
Neceſſity of keeping the joints in their firſt ſtate.

We think therefore that it is of great conſequence to keep the joints in their *firſt* ſtate if poſſible; and that the ſtrength (as far as it depends on the mortar) is greatly diminiſhed by their opening; eſpecially when the mortar has acquired conſiderable hardneſs, which it will do in a month or ſix weeks, if it be good. The coheſion given by mortar is indeed a mere trifle, when oppoſed to a force which tends to open the joints, acting, as it generally does, with the tranſverſe force of a lever: but in ſituations where the overload on any particular archſtones tends to puſh them down through between their neighbours, like wedges, the coheſion of the mortar is then of very great conſequence.

We muſt make another obſervation. Mr Perronet's ingenious proceſs tended very effectually to cloſe the joints. In doing this, the forces which he brought into action had little to oppoſe them; but as ſoon as they were cloſed, the contact of the parts formerly open oppoſed an obſtruction incomparably greater, and immediately balanced a force which was but juſt able to turn the ſtone gently about the two edges in which it touched the adjoining ſtones. This is an important remark, though ſeemingly very trifling; and we wiſh the practitioner to have a very clear conception of it; but it would take a multitude of words to explain it. It is worth an experiment. Form a little arch of wooden blocks; and form one of theſe ſo, that when they are all reſting on the centering, it may be open at the outer joint—Remove the centering—Then preſs on the arch at ſome diſtance from the open joint.—You will find that a very ſmall preſſure will make the arch bend till that joint cloſes—Preſs a little harder, and the arch will bend more, and the next joint will open.—Thus you will find that, by preſſing alternately on each ſide of the open joint, that ſtone can eaſily be made to flap over to either ſide; and that immediately after this is done the reſiſtance increaſes greatly. This ſhews clearly, that a very moderate force, judiciouſly employed, will cloſe the joints, but will not preſs the parts ſtrongly together. The joints therefore are *cloſed*, but *no more than cloſed*, and are hanging only by the edges by which they were hanging while the joints were open. The arch, therefore, though apparently cloſe and firm, is but looſe and tottering. Mr Perronet ſays, that his arches were firm, becauſe hardly a ſtone was obſerved to chip or ſplinter off at the edges by the ſettlement. But he had done every thing to prevent this, by digging out the mortar from between the headers, to the depth of two inches, with ſaws made on purpoſe. But we are well informed, that before the year 1791 (twenty years after the erection) the arches at Neuilly had ſunk very ſenſibly, and that very large ſplinters had flown off in ſeveral places. It could not be otherwiſe. The original conſtruction was too bold; we may ſay needleſsly and oſtentatiouſly bold. A very gentle ſlope of the roadway, which would not have ſlackened the mad gallop of a ducal carriage, nor ſenſibly checked the laborious pull of a loaded waggon, and a proper difference in the ſize of the arches, would have made this wonderful bridge incomparable ſtronger, and alſo much more elegant and pleaſing to the eye. Indeed, it is far from being as handſome as it might have been. The ellipſe is a moſt pleaſing figure to every beholder; but this is concealed as much as poſſible, and it is attempted to give the whole the appearance of a tremendous lintel. It has the oppreſſive look of danger. It will not be of long duration. The bridge at Mantz is ſtill more exceptionable, becauſe its piers are tall and ſlender. If any one of the arches fails, the reſt muſt fall in a moment. An arch of Blackfriars Bridge might be blown up without diſturbing its neighbours.

29
Mr Perr net's conſtruction too bold.

30
A bad m thod of ſtriking t centre.

Mr Perronet mentions another mode of ſtriking the centering, which he ſays is very uſual in France. Every ſecond bridging is cut out. Some time after, every ſecond of the remainder; after this, every ſecond of the remainder; and ſo on till all are removed. This is never practiſed in this country, and is certainly a very bad method. It leaves the arch hanging by a number of diſtant points; and it is wonderful that any arch can bear this treatment.

Our architects have generally proceeded with extreme caution. Wherever they could, they ſupported the centering by intermediate pillars, even when it was a truſſed centre, having a tie-beam reaching from ſide to ſide. The centre was made to reſt, not immediately on theſe pillars, but on pieces of timber formed like acute wedges, placed in pairs, one above the other, and having the point of the one on the thick end of the other. Theſe wedges were well ſoaped and rubbed with black lead, to make them ſlippery. When the centres are to be ſtruck, men are ſtationed at each pair of the wedges with heavy mauls. They are directed to ſtrike together on the oppoſite wedges. By this operation the whole centering deſcends together; or, when any part of the arch is obſerved to have opened its joints on the upper ſide, the wedges below that part are ſlackened. The framing may perhaps bend a little, and allow that part to ſubſide. If any part of the arch is obſerved to open its joints on the under ſide, the wedges below that part are allowed to ſtand after the reſt have been ſlackened. By this proceſs, the whole comes down gradually, and as ſlowly as we pleaſe, and the defects of every part of the arch may be attended to. Indeed the caution and moderation of our builders have commonly been ſuch, that few defects have been allowed to ſhew themſelves. We are but little acquainted with joints opening to the extent of two inches, and in ſuch a caſe would probably

31
The common method in Britain.

produced and excited in a frame of carpentry, which is ſettling and changing its ſhape, even though it be not very complicated; far leſs are we poſſeſſed of a clear view of what happens in a maſs of maſonry in ſimilar conditions. Therefore, though we ſpeak with the ſtrong belief of our being right, we ſpeak with a ſenſe of our fallibility, and with great deference to the judgment of eminent and experienced architects and engineers. We ſhould conſider their free and candid criticiſms as the higheſt favour; and we even ſolicit them, with aſſurances of thanks, and that we will take ſome opportunity, before the cloſe of this work, to acknowledge and correct our miſtakes. We even preſume to hope, that the liberal minded artiſt will be pleaſed with this opportunity which we give him of increaſing the national ſtock of knowledge. Let mutual jealouſy and rivalſhip reign in the breaſts, and prompt the exertions, of our reſtleſs neighbours on the continent—let them think that the dignity of man conſiſts in perpetual warfare, in which every individual feels himſelf indebted only to himſelf, freed from all the ſweet ties of domeſtic partiality, of friendſhip, and of patriotic attachment. We hope that the hearts of Britons will long continue to be warmed and *fortified* by the thoughts of mutual aſſiſtance, mutual co-operation, mutual attachment, and a patriotic preference of their countrymen to all other men. While theſe ſentiments are regulated by unſhaken honeſty, by candour, and by Chriſtian charity, we ſhall be ſecured from the *errors* of partial attachments, and yet enjoy all the pleaſures of unſophiſticated nature. Families will ſtill be bound together by the affectionate ties of blood; and the whole frame of Britiſh ſociety will be in harmony with the bonds which connect the members of each family, by their endleſs croſſings and intermixings. In this ſtate, the ſtate of ſocial nature, the man of talents will not lock up all the fruits of his exertions in his own breaſt, but will feel a pleaſure in imparting them to a ſociety that is dear to him, and on which he depends for all his beſt enjoyments. Nothing will hold the good man back when this is in his power, but the virtuous uſe which he can make of his ſuperiority in the diſcharge of his own little circle of duties. This is all that is required of true patriotiſm; and it is not too much to be expected from Britons, who feel a pleaſure in viewing their country as the great ſchool of the arts, under the patronage of a ſovereign who has done more for their improvement than all the other princes of Europe, and who (we are well aſſured) is now meditating a plan which muſt be highly gratifying to every eminent profeſſor of the arts.

34
The ſubject of this article connected with the conſtruction of wooden bridges.

THE ſubject which we have been conſidering is very cloſely connected with the conſtruction of wooden bridges. Theſe are not always conſtructed on the ſole principles of equilibrium, by means of mutual abutment. They are ſtiff frames of carpentry, where, by a proper diſpoſition, beams are put into a ſtate of extenſion, as well as of compreſſion, ſo as to ſtand in place of ſolid bodies as big as the ſpaces which the beams incloſe; and thus we are enabled to couple two, three, or four of theſe together, and ſet them in abutment with each other like mighty archſtones. We ſhall cloſe this article, therefore, with two or three ſpecimens of wooden bridges, diſpoſed in a ſeries of progreſſive compoſition, ſo as to ſerve as a ſort of introduction to the art in general, and furniſh a principle which will enable the intelligent and cautious artiſt to puſh it with confidence as far as it can go.

Plate XVI.

The general problem is this. Suppoſe that a bridge is to be thrown over the ſpace AB (fig. 9.), and that this is too wide for the ſtrength of the ſize of timber which is at our command; how may this beam AB be ſupported with ſufficient effect? There are but two ways in which the middle point C (where the greateſt ſtrain is) can be ſupported: 1. It may be ſuſpended by two ropes, iron rods, or wooden ties, DC, EC, made faſt to two firm points D, E, above it; or it may reſt on the ridge of two rafters *d* C, *e* C, which reſt on two firm points *d*, *e* below it. 2. It may be ſupported by connecting it with a point ſo ſupported; and this connection may be formed either by ſuſpending it from this point, or by a poſt reſting on it. Thus it may hang, by means of a rod or a king-poſt FC, from the ridge F of two rafters AF, BF; or it may reſt on the ſtrut C *f*, whoſe lower extremity *f* is carried by the ropes, rods, or wooden ties A *f*, B *f*.

Whichſoever of theſe methods we employ, it follows, from the principles of carpentry, that the ſupport given to the point C is ſo much the more powerful, as we make the angle DCE, or *d* C *e*, or the equivalent angles AFB, or A *f* B, more acute.

Each of theſe methods may be ſuppoſed equally ſtrong. Our choice will depend chiefly on the facility of finding the proper points of ſupport D, E, *d*, *e*; except in the ſecond caſe, where we require no fixed points but A and B. The ſimple forms of the firſt caſe require a great extent of figure. Very rarely can we ſuſpend it from points ſituated as D and E. It is even ſeldom that we have depth enough of bank to allow the ſupport of the rafters *d* C, *e* C; but we can always find room for the ſimple truſs AFB. This therefore is the moſt uſually practiſed.

35
The uſual and ſimpleſt method of conſtructing ſuch bridges.

In the conſtruction, we muſt follow the maxims and directions preſcribed in the article CARPENTRY of this volume, and the article ROOF of the *Encycl.* The beams FA, FB muſt be mortiſed into AB, in the firmeſt manner, and there ſecured with ſtraps and bolts; and the middle muſt hang by a ſtrap attached to the king poſt FC, or to the iron rod that is uſed for a king poſt. No mortiſing in the point C muſt be employed; it is unneceſſary, and it is hurtful, becauſe it weakens the beam, and becauſe it lodges water, and ſoon decays by rot. The beſt practice is not to ſuſpend the beam immediately by this ſtrap, but to let it reſt, as in fig. 10. on a beam C, which croſſes the bridge below, and has its other end ſupported in the ſame manner by the other truſs.

It is evident that the length of the king poſt has no effect on the ſupport of C. We may therefore contract every thing, and preſerve the ſame ſtrength of ſupport, by finding two points *a* and *b* (fig. 11.) in the banks, at a moderate diſtance below A and B, and ſetting up the rafters *a* F, *b* F, and ſuſpending C from the ſhortened king poſt. In this conſtruction, when the beam AB reſts on a croſs bearer, as is drawn here, the ſtruts *a* F, *b* F are kept clear of it. No connection between them is neceſſary, and it may be hurtful, by inducing croſs ſtrains on both. It will, however, greatly increaſe

this plane with the ſurface of the fluid ; and the centre of preſſure upon a plane parallel to the horizon, or upon any plane where the preſſure is uniform, is the ſame as the centre of gravity of that plane.

CENTREVILLE, the chief town of Queen Ann's co. and on the E. ſide of Cheſapeak bay in Maryland. It lies between the forks of Corſica creek, which runs into cheſter River and has been lately laid out; 18 miles S. of Cheſter; 34 S. E. by E. of Baltimore, and 95 S. W. by S. of Philadelphia. N. lat. 39. 6.—*Morse.*

CENTROBARICO, the ſame as centre of gravity.

CENTROBARIC METHOD, is a method of determining the quantity of a ſurface or ſolid, by means of the generating line or plane and its centre of gravity. The doctrine is chiefly compriſed in this theorem:

Every figure, whether ſuperficial or ſolid, generated by the motion of a line or plane, is equal to the product of the generating magnitude and the path of its centre of gravity, or the line which its centre of gravity deſcribes.

CERUSE, or WHITE-LEAD, is a ſubſtance ſo much uſed in painting, and for other purpoſes, that numerous modes have been employed for the preparation of it. Of the moſt common of theſe, a ſufficient account has been given in the Encyclopædia (ſee CERUSE, and the ſame word CHEMISTRY-*Index)*; but Lord Dundonald has diſcovered a more expeditious and facile method than any of them, which becomes the more uſeful, as the ſubſtance with which it is effected has been hitherto rejected by the chemical world as a *caput mortuum.*

His lordſhip directs common lead to be reduced to a calx, but not too fine, and to have a proportion of five-ſixth parts thereof, intimately mixed with muriate, or ſolution of potaſs. In this ſtate, he directs it to be frequently ſtirred, in order to have the new ſurfaces of the mixture expoſed to the carbonic acid of atmoſpheric air; as his lordſhip obſerves, that the effects of the carbonic acid on the alkali exiſting in the preſent ſtate of the mixture is eſſentially neceſſary, in order to effect the intended purpoſe. In this ſtate, it is to be frequently ſprinkled with water; and, after the calx has been long enough immerſed with the muriate to be ſufficiently operated upon, the muriate is to be levigated by common water from the calx, and to be concentrated by evaporation, in order to be made uſe of at a future period with other calx. The calx is to be afterwards ground, levigated, and dried for uſe.

For this diſcovery, his lordſhip obtained a patent on the 18th of Auguſt 1797; and the ſucceſs which has attended the former patents of this ſcientific nobleman leads us to conclude, that the preſent diſcovery is entitled to the attention of the public.

CHACTAWS, or flat heads, are a powerful, hardy, ſubtile and intrepid race of Indians, who inhabit a very fine and extenſive tract of hilly country, with large and fertile plains intervening, between the Alabama and Miſſiſſippi rivers, and in the weſtern part of the ſtate of Georgia. This nation had, not many years ago, 43 towns and villages, in three diviſions, containing 12,123 ſouls, of which 4,041 were fighting men. They are called by the traders Flatheads, all the males having the fore and hind part of their ſkulls artificially flattened when young. Theſe men, unlike the Muſcogulges, are ſlovenly and negligent in every part of their dreſs, but otherwiſe are ſaid to be ingenious, ſenſible, and virtuous men, bold and intrepid, yet quiet and peaceable. Some late travellers, however, have obſerved that they pay little attention to the moſt neceſſary rules of moral conduct, at leaſt that unnatural crimes were too frequent among them. Different from moſt of the Indian nations bordering on the United States, they have large plantations or country farms, where they employ much of their time in agricultural improvements, after the manner of the white people. Although their territories are not ¼th ſo large as thoſe of the Muſcogulge confederacy, the number of inhabitants is greater. The Chactaws and Creeks are inveterate enemies to each other.—*Morse.*

CHAGRE, a river and town in Terra Firma, S. America. The river opens to the N. Sea, and was formerly called Lagortas, from the number of alligators in it; has its ſource in the mountains near Cruces, and its mouth is in N. lat. 9. where there is a ſtrong fort, built on a ſteep rock, on the E. ſide, near the ſea ſhore. This fort has a commandant, and lieutenant, and the garriſon is draughted from Panama, to which you go by this river, landing at Cruces, about 5 leagues from Panama, and thence one travels by land to that city. Oppoſite to fort Chagre is the royal cuſtom-houſe. Here the river is broadeſt, being 120 toiſes over; whereas, at Cruces, where it begins to be navigable, it is only 20 toiſes wide; from the town of Chagre, to the mouth of the river, is 21 miles N. W. by W. but meaſuring by water is 43 miles. There is at Cruces an alcalde, who lives at the cuſtom-houſe, and takes an account of all goods on the river. Chagre fort was taken by admiral Vernon, in 1740.—*ib.*

CHAMBERS (Sir William), the celebrated architect, was deſcended of the ancient family of Chalmers in Scotland, barons of Tartas, in France. His grandfather ſuffered conſiderably in his fortune by ſupplying Charles XII. of Sweden with money, &c. which that monarch repaid in baſe coin. Sir William's father reſided ſeveral years in Sweden to recover his claims; and there Sir William was born, and, at eighteen years of age, appointed ſupercargo to the Swediſh Eaſt India company. From a voyage which he made to China, he brought home the Aſiatic ſtyle of ornament, in tents, temples, moſques, and pagodas. Theſe ornaments (through the intereſt of lord Bute) he was enabled to apply in the gardens at Kew. Patroniſed by the princeſs dowager and the king, Mr Chambers had much of the faſhionable buſineſs of the day. Under Burke's reform, he was appointed ſurveyor-general of the board of works. Somerſet-houſe was worth to him at leaſt £.2000 a year. His *Chef d'œuvres* are his ſtaircaſes, particularly thoſe at Lord Beſborough's, Lord Gower's, and the Royal and Antiquarian Societies. The terrace behind Somerſet houſe is a bold effort of conception. His deſigns for interior arrangements were excellent. His Treatiſe on Civil Architecture alone will immortalize his name. In private life, Sir William was hoſpitable, kind, and amiable. His ſon married Miſs Rodney; Mr Cotton, Mr Innis, and Mr Harward, married his beautiful daughters. Having been abſtemious in his youth, Sir William's conſtitution did not begin to break till he was ſeventy years of age. For the laſt three years, he was kept alive by wine and oxygenated air; and died on the 5th of March 1796. His celebrity will be laſting in the works which he has left; and, as he was equally ſkilled in the theory and practice of the arts which he profeſſed, his precepts are as valuable as his works. At his death, he was fellow of the Royal and Antiquarian Societies, treaſurer of the Royal Academy, ſurveyor-general of the board of works, and knight of the Swediſh order of the Polar Star.

CHAMBERSBURG, a poſt town, in Pennſylvania, and the chief of Franklin co. It is ſituated on the eaſtern branch of Conogocheague creek, a water of Potowmac River in a rich and highly cultivated country, and healthy ſituation.—Here are about 200 houſes, 2 Preſbyterian churches, a ſtone gaol, a handſome court-houſe, built of brick, a paper and merchant mill. It is 58 miles E. by S. of Bedford, 11 N. W. of Shippenſburg, and 157 W. of Philadelphia. N. lat. 39. 53. W. long. 77. 30.—*Morſe.*

CHAMBLEE *River* or *Sorell*, a water of the St Lawrence, iſſuing from lake Champlain, 300 yards wide when loweſt. It is ſhoal in dry ſeaſons; but of ſufficient breadth for rafting lumber, &c. ſpring and fall. It was called both Sorell and Richlieu when the French held Canada.—*ib.*

CHAMBLEE *Fort*, is handſome and well built, on the margin of the river of the ſame name, about 12 or 15 miles S. W. from Montreal, and N. of St John's fort. It was taken by the Americans, Oct. 20, 1775, and retaken by the Britiſh, Jan. 18, 1776. N. lat. 45. 45.—*ib.*

CHAMFER, or CHAMFERET, an ornament, in architecture, conſiſting of half a ſcotia; being a kind of ſmall furrow or gutter on a column.

CHAMPLAIN, a lake next in ſize to lake Ontatario, and lies E. N. E. from it, forming a part of the dividing line between the ſtates of New-York and Vermont. It took its name from a French governor, who was drowned in it. It was before called Corlaer's Lake. Reckoning its length from Fairhaven to St John's, a courſe nearly N. it is about 200 miles; its breadth is from 1 to 18 miles, being very different in different places; the mean width is about 5 miles; and it occupies about 500,000 acres. Its depth is ſufficient for the largeſt veſſels. There are in it above ſixty iſlands of different ſizes; the moſt conſiderable are North and South Hero, and Motte iſland. North Hero, or Grand Iſle, is 24 miles long and from 2 to 4 wide. It receives at Ticonderoga the waters of Lake George from the S. S. W. which is ſaid to be 100 feet higher than the waters of this lake. Half the rivers and ſtreams which riſe in Vermont fall into it. There are ſeveral which come to it from New-York ſtate and ſome from Canada; to which laſt it ſends its own waters, a N. courſe, through Sorell or Chamblee river, into the St Lawrence. This lake is well ſtored with fiſh; particularly ſalmon, ſalmon-trout, ſturgeon and pickerel; and the land on its borders, and on the banks of its rivers, is good.

The rocks in ſeveral places appear to be marked, and ſtained, with the former ſurface of the lake, many feet higher than it has been ſince its diſcovery in 1608. The waters generally riſe from about the 20th of April, to the 20th of June, from 4 to 6 feet; the greateſt variation is not more than 8 feet. It is ſeldom entirely ſhut up with ice, until the middle of January. Between the 6th and 15th of April the ice generally goes off; and it is not uncommon for many ſquare miles of it to diſappear in one day.—*Morſe.*

CHAMPLAIN, a townſhip the moſt northerly in Clinton co. New-York, which takes its name from the lake on which it lies. It was granted to ſome Canadian and Nova-Scotia refugees, who were either in the ſervice of the United States, during the war, or fled to them for protection. The indigence or ill habits of theſe people occaſioned the breaking up of the ſettlement; and a better ſet of inhabitants have now taken their place. The lands are fertile; and two rivers run through it, well ſtored with fiſh. It has 575 inhabitants, and 3 ſlaves. By the ſtate cenſus of 1796, 76 of the inhabitants are electors.—*ib.*

CHAPPE (Jean d'Auteroche), a French aſtronomer, was born at Mauriac, in Auvergne, March 2. 1728. A taſte for drawing and mathematics appeared in him at a very tender age; and he owed to Dom Germain a knowledge of the firſt elements of mathematics and aſtronomy. M. Caſſini, after aſſuring himſelf of the genius of this young man, undertook to improve it. He employed him upon the map of France, and the tranſlation of Halley's tables, to which he made conſiderable additions. The king charged him in 1753 with drawing the plan of the county of Bitche, in Lorraine, all the elements of which he determined geographically. He occupied himſelf greatly with the two comets of 1760; and the fruit of his labour was his elementary treatiſe on the theory of thoſe comets, enriched with obſervations on the zodiacal light, and on the aurora borealis. He ſoon after went to Tobolſk, in Siberia, to obſerve the tranſit of Venus over the ſun; a journey which greatly impaired his health. After two years abſence he returned to France in 1762, where he occupied himſelf for ſome time in putting in order the great quantity of obſervations he had made. M. Chappe alſo went to obſerve the next tranſit of Venus, viz. that of 1769, at California, on the weſt ſide of North America, where he died of a dangerous epidemic diſeaſe, the 1ſt of Auguſt 1769. He had been named adjunct aſtronomer to the academy the 17th of January 1759.

The publiſhed works of M. Chappe, are, 1. The Aſtronomical Tables of Dr Halley, with Obſervations and Additions, in 8vo, 1754. 2. Voyage to California, to Obſerve the Tranſit of Venus over the Sun, the 3d of June 1769; in 4to, 1772. 3. He had a conſiderable number of papers inſerted in the Memoirs of the Academy, for the years 1760, 1761, 1764, 1765. 1766, 1767, and 1768; chiefly relating to aſtronomical matters.

CHAPPEL-HILL, a poſt town in Orange co. N. Carolina, ſituated on a branch of Newhope creek, which empties into the N. W. branch of Cape Fear River. This is the ſpot choſen for the ſeat of the Univerſity of North-Carolina. Few houſes are as yet erected; but a part of the public buildings were in ſuch forwardneſs, that ſtudents were admitted, and education commenced in Jan. 1796. The beautiful and elevated ſcite of this town commands a pleaſing and extenſive view of the ſurrounding country; 12 miles S. by E. of Hillſborough, and 472 S. W. of Philadelphia. N. lat. 35. 40. W. long. 79. 6.—*ib.*

UNIVERSAL CHARACTERS, could they be introduced,

duced, would contribute ſo much to the diffuſion of uſeful knowledge, that every attempt to make ſuch a ſcheme ſimple and practicable is at leaſt entitled to notice. Accordingly, in the *Encyclopædia*, under the word CHARACTER, a ſhort account is given of the principal plans of univerſal characters which had then fallen under our obſervation; but ſince that article was publiſhed, a new method of writing, by which the various nations of the earth may communicate their ſentiments to each other, has been propoſed by *Thomas Northmore*, Eſq; of Queen-ſtreet, Mayfair. It bears ſome reſemblance to that which we have given from the *Journal Literaire*, 1720, but it is not the ſame; and of the two, Mr Northmore's is perhaps the moſt ingenious. The ground-work of the ſuperſtructure differs not indeed from that of the journaliſt, being this in both, " That if the ſame numerical *figure* be made to repreſent the *ſame word* in the various languages upon earth, an univerſal character is immediately obtained." The only objection which our author or his friends ſaw to ſuch a plan, originates in the diverſity of idioms; but, as he truly obſerves, every ſchoolboy has this difficulty to encounter as often as he conſtrues Terence.

Such then was Mr Northmore's original plan: but he ſoon perceived that it was capable of conſiderable improvement; for, inſtead of uſing a figure for *every* word, it will be neceſſary to apply one only to every *uſeful* word; and we all know how few words are abſolutely neceſſary to the communication of our thoughts. Even theſe may be much abbreviated by the adoption of certain *uniform fixed* ſigns (not amounting to above 20), for the various caſes, numbers, genders, degrees of compariſon, of nouns, tenſes, and moods, of verbs, &c. All words of negation, too, may be expreſſed by a prefixed ſign. A few inſtances will beſt explain the author's meaning.

Suppoſe the number 5 to repreſent the word *ſee*,
6 — — *a man*,
7 — — *happy*,
8 — — *never*,
9 — — *I*.

" I would then (ſays he) expreſs the tenſes, genders, caſes, &c. *in all languages*, in ſome ſuch *uniform* manner as following:

(1) 5 = *preſent tenſe*, — ſee,
(2) .5 = *perfect tenſe*, — ſaw,
(3) :5 = *perfect participle*, — ſeen,
(4) 5: = *preſent participle*, — ſeeing,
(5) 5· = *future*, — — will ſee,
(6) $\underline{5}$ = *ſubſtantive*, — ſight,
(7) $\underline{\underline{5}}$ = *perſonal ſubſtantive*, — ſpectator,
(8) 6 = *nominative caſe*, — a man,
(9) $\ddot{6}$ = *genitive*, — — of a man,
(10) $\dddot{6}$ = *dative*, — — to a man,
(11) $\overset{\frown}{6}$ = *feminine*, — — a woman,
(12) +6 = *plural*, — — men,
(13) 7 = *poſitive*, — — happy,
(14) $\hat{7}$ = *comparative*, — happier,
(15) $\overset{\wedge\wedge}{7}$ = *ſuperlative*, — happieſt,
$\underline{7}$ = as above, N° 6. — happineſs,
(16) —7 = *negation*, — — unhappy,

" From the above ſpecimen, I ſhould find no difficulty in comprehending the following ſentence, though it were written in the language of the Hottentots: 9, 8, .5, —$\hat{7}$, $\overset{\frown}{6}$. *I never ſaw a more unhappy woman.*

" Thoſe languages which do not uſe the pronoun prefixed to the verb, as the Greek and Roman, &c. may apply it, in a ſmall character, ſimply to denominate the perſon; thus, inſtead of 9, 8, .5, *I never ſaw*; they may write, 8, $_9$.5, which will ſignify that the verb is in the firſt perſon, and will ſtill have the ſame meaning."

Our author ſeems confident that, according to this ſcheme of an univerſal character, about 20 ſigns, and leſs than 10,000 *choſen* words (ſynonyms being ſet aſide), would anſwer all the ends propoſed; and that foreigners, by referring to their numerical dictionary, would eaſily comprehend each other. He proceeds next to ſhew how appropriate ſounds may be given to his ſigns, and an univerſal *living language* formed from the univerſal *characters*.

To attain this end, he propoſes to diſtinguiſh the ten numerals by ten monoſyllabic names of eaſy pronunciation, and ſuch as may run without difficulty into one another. To illuſtrate his ſcheme, however, he calls them for the preſent, by their common Engliſh names; but would pronounce each number made uſe of by uttering ſeparately its component parts, after the manner of accountants. Thus let the number 6943 repreſent the word *horſe*, he would not, in the univerſal language, call a horſe *ſix thouſand nine hundred and forty three*, but *ſix*, *nine*, *four*, *three*, and ſo on for all the words of a ſentence, making the proper ſtop at the end of each. In the ſame manner, a diſtinct appellation muſt be appropriated to each of the prefixed ſigns, to be pronounced immediately after the numeral to which it is an appendage. Thus if *plu* be the appellation or the ſign of the plural number, *ſix*, *nine*, *four*, *three*, *plu* will be *horſes*.

" Thus (ſays our author), I hope, it is evident that about 30 or 40 diſtinct ſyllables are ſufficient for the above purpoſe; but I am much miſtaken if *eleven* only will not anſwer the ſame end. This is to be done by ſubſtituting the firſt 20 or 30 numerals for the ſigns, and ſaying, as in algebra, that a term is in the power of ſuch a number, which may be expreſſed by the ſimple word *under*. *Ex. gr.* Let 6943 repreſent the word *horſe*; and ſuppoſe 4 to be the ſign of the plural number, I would write the word thus, $\frac{4}{6943}$; and pronounce it, ſix, nine, four, three, in the power of or *under* four. By theſe means eleven diſtinct appellations would be ſufficient, and time and uſe would much abbreviate the pronunciation."

To refuſe the praiſe of ingenuity to this contrivance for an univerſal language would be very unjnſt; but elocution in this manner would be ſo very tedious, that ſurely the author himſelf, when he thinks more coolly on the ſubject, will perceive, that in the living ſpeech its defects would more than balance its advantages. A *pangraph*, as he calls his univerſal character, would indeed be uſeful, and is certainly practicable ; a *panleg* (if we may form ſuch a word) would not be very uſeful, unleſs it were much more perfect than it could be made according to the plan before us.

CHARLES *River* in Maſſachuſetts, called anciently *Quinobequin*, is a conſiderable ſtream, the principal branch of which riſes from a pond bordering on Hopkinton. It paſſes through Holliſton and Bellingham, and divides Medway from Medfield, Wrentham, and Franklin, and thence into Dedham, where, by a curious bend, it forms a peninſula of 900 acres of land. A ſtream called Mother Brook, runs out of this river in this town, and falls into Neponſit River, forming a natural canal, uniting the two rivers, and affording a number of excellent mill-ſeats. From Dedham the courſe of the river is northerly, dividing Newton from Needham, Weſton, and Waltham, paſſing over romantic falls ; it then bends to the N. E. and E. through Watertown and Cambridge, and paſſing into Boſton harbor, mingles with the waters of Myſtic River at the point of the peninſula of Charleſtown. It is navigable for boats to Watertown, 7 miles. The moſt remarkable bridges on this river are thoſe which connect Boſton with Charleſtown and Cambridge. There are 7 paper mills on this river, beſides other mills. —*Morſe.*

Charles *Co.* on the weſtern ſhore of Maryland, lies between Potowmack and Patuxent rivers. Its chief town is Port Tobacco, on the river of that name. Its extreme length is 28 miles, its breadth 24, and it contains 20,613 inhabitants, including 10,085 ſlaves. The country has few hills, is generally low and ſandy, and produces tobacco, Indian corn, ſweet potatoes, &c. —*ib.*

Charles City *Co.* in Virginia, lies between Chickahominy and James rivers. It contained formerly part of what now forms Prince George's co. It has 5588 inhabitants, including 3141 ſlaves.—*ib.*

Charles, a cape of Virginia, in about N. lat. 37. 15. It is on the N. ſide of the mouth of Cheſapeak bay, having Cape Henry oppoſite to it.—*ib.*

Charles, a cape on the S. W. part of the ſtrait entering into Hudſon Bay. N. lat. 62. 40. W. long. 75. 15.—*ib.*

CHARLESTON, a diſtrict in the Lower country of S. Carolina, ſubdivided into 14 pariſhes. This large diſtrict, of which the city of Charleſton is the chief town, lies between Santee and Combahee rivers. It pays £.21,473-14-6 ſterling taxes. It ſends to the ſtate legiſlature 48 repreſentatives and 13 ſenators, and 1 member to Congreſs. It contains 66986 inhabitants, of whom, only 16352 are free.—*ib.*

Charleston, the metropolis of S. Carolina, is the moſt conſiderable town in the ſtate ; ſituated in the diſtrict of the ſame name, and on the tongue of land formed by the confluent ſtreams of Aſhley and Cooper, which are ſhort rivers, but large and navigable. Theſe waters unite immediately below the city, and form a ſpacious and convenient harbor ; which communicates with the ocean juſt below Sullivan's Iſland ; which it leaves on the N. 7 miles S. E. of Charleſton. In theſe rivers the tide riſes, in common, about 6½ feet ; but uniformly riſes 10 or 12 inches more during a night-tide. The fact is certain ; the cauſe unknown. The continual agitation which the tides occaſion in the waters which almoſt ſurround Charleſton—the refreſhing ſea-breezes which are regularly felt, and the ſmoke ariſing from ſo many chimneys, render this city more healthy than any part of the low country in the ſouthern ſtates. On this account it is the reſort of great numbers of gentlemen, invalids from the W. India iſlands, and of the rich planters from the country, who come here to ſpend the ſickly months, as they are called, in queſt of health and of the ſocial enjoyments which the city affords. And in no part of America are the ſocial bleſſings enjoyed more rationally and liberally than here. Unaffected hoſpitality—affability—eaſe of manners and addreſs—and a diſpoſition to make their gueſts welcome, eaſy and pleaſed with themſelves, are characteriſtics of the reſpectable people of Charleſton. In ſpeaking of the capital, it ought to be obſerved, for the honour of the people of Carolina in general, that when in common with the other colonies, in the conteſt with Britain, they reſolved againſt the uſe of certain luxuries, and even neceſſaries of life ; thoſe articles, which improve the mind, enlarge the underſtanding, and correct the taſte, were excepted ; the importation of books was permitted as formerly.

The land on which the town is built, is flat and low, and the water brackiſh and unwholeſome. The ſtreets are pretty regularly cut, and open beautiful proſpects, and have ſubterranean drains to carry off filth and keep the city clean and healthy ; but are too narrow for ſo large a place and ſo warm a climate. Their general breadth is from 35 to 66 feet. The houſes which have been lately built, are brick, with tiled roofs. The buildings in general are elegant, and moſt of them are neat, airy and well furniſhed. The public buildings are, an exchange, a ſtate-houſe, an armoury, a poor-houſe, and an orphan's houſe. Here are ſeveral reſpectable academies. Part of the old barracks has been handſomely fitted up, and converted into a college, and there are a number of ſtudents ; but it can only be called as yet a reſpectable academy. Here are two banks—a branch of the national bank, and the S. Carolina bank, eſtabliſhed in 1792. The houſes for public worſhip are two epiſcopal churches, two for Independents, one for Scotch Preſbyterians, one for Baptiſts, one for German Lutherans, two for Methodiſts, one for French Proteſtants, a meeting-houſe for Quakers, a Roman Catholic chapel, and a Jewiſh ſynagogue.

Little attention is paid to the public markets ; a great proportion of the moſt wealthy inhabitants having plantations from which they receive ſupplies of almoſt every article of living. The country abounds with poultry and wild ducks. Their beef, mutton and veal are not generally of the beſt kind ; and few fiſh are found in the market.

In 1787, it was computed that there were 1600 houſes in this city, and 15,000 inhabitants, including 5,400 ſlaves ; and what evinces the healthineſs of the place, upwards of 200 of the white inhabitants were above 60 years of age. In 1791, there were 16,359 inhabitants, of whom 7684 were ſlaves. This city has often ſuffered much by fire, the laſt and moſt deſtructive happened as late as June, 1796.

Charleſton was incorporated in 1783, and divided into three wards, which choſe as many wardens, from among whom the citizens elect an intendant of the city. The intendant and wardens form the city-council, who have power to make and enforce bye-laws for the regulation of the city.

The value of exports from this port, in the year ending Nov. 1787, amounted to £.505,279·19·5 ſterling. The number of veſſels cleared from the cuſtom-houſe the ſame year, was 947, meaſuring 62,118 tons; 735 of theſe, meaſuring 41,531 tons, were American; the others belonged to Great-Britain, Ireland, Spain, France, and the United Netherlands. In the year 1794, the value of exports amounted to 3,846,392 dollars. It is 60 miles S. W. by S. of Georgetown; 150 E. by S. of Auguſta; 497 S. by W. of Richmond; 630 S. W. by S. of Waſhington city; 763 S. W. by S. of Philadelphia; and 1110 S. W. of Boſton. The light-houſe lies in N. lat. 32. 41. 52. White Point at the S. end of the town, N. lat. 32. 44. 30. W. long. 80. 39. 45.

Knoxville, the capital of the ſtate of Tenneſſee, is much nearer to this than to any ſea-port-town on the Atlantic Ocean. A waggon road of only 15 miles is wanted to open the communication; and the plan is about to be executed by the ſtate.—*ib.*

CHARLESTOWN, a poſt-town in Cecil co. Maryland, near the head of Cheſapeak bay; 6 miles E. N. E. from the mouth of Suſquehannah River; 10 W. S. W. from Elkton, and 50 S. W. by W. from Philadelphia. Here are about 20 houſes, chiefly inhabited by fiſhermen employed in the herring fiſhery. N. lat. 39. 34.—*ib.*

CHARLESTOWN, a townſhip in Montgomery co. New-York, on the S. ſide of Mohawk river, about 32 miles W. of Schenectady. By the ſtate cenſus of 1796, 456 of the inhabitants are electors.—*ib.*

CHARLESTOWN, a townſhip in Maſon co. Kentucky; ſituated on the Ohio at the mouth of Lauren's creek. It contains but few houſes, and is 6 miles N. of Waſhington, and 60 N. E. of Lexington. N. lat. 38. 43.—*ib.*

CHARLESTOWN, a townſhip in Cheſter co. Pennſylvania.—*ib.*

CHARLESTOWN, a poſt-town in Cheſhire co. New-Hampſhire, on the E. ſide of Connecticut River 30 miles S. of Dartmouth College; upwards of 70 N. of Northampton, 116 N. of W. of Boſton, 80 W. by N. of Portſmouth, and 341 N. N. E. of Philadelphia. It was incorporated in 1753, and contains 90 or 100 houſes, a Congregational church, a court-houſe and an academy. The road from Boſton to Quebec paſſes through this town. N. lat. 43. 16. W. long. 72. 19. A ſmall internal trade is carried on here.—*ib.*

CHARLESTOWN, the principal town in Middleſex co. Maſſachuſetts, called *Miſhawun* by the aboriginal inhabitants, lies N. of Boſton, with which it is connected by Charles-River Bridge. The town, properly ſo called, is built on a peninſula, formed by Myſtic River on the E. and a bay, ſetting up from Charles-River, on the W. It is very advantageouſly ſituated for health, navigation, trade, and manufactures of almoſt all the various kinds. A dam acroſs the mouth of the bay, which ſets up from Charles-River, would afford a great number of mill-ſeats for manufactures. Bunker's, Breed's, and Cobble (now Barrell's) hills, are celebrated in the hiſtory of the American Revolution. The ſecond hill has upon its ſummit a monument erected to the memory of major gen. Warren, near the ſpot where he fell, among the firſt ſacrifices to American liberty. The brow of the hill begins to be ornamented with elegant houſes. All theſe hills afford elegant and delightful proſpects of Boſton, and its charmingly variegated harbor, of Cambridge and its colleges, and of an extenſive tract of highly cultivated country. It contains within the neck or pariſh about 250 houſes, and about 2000 inhabitants. The only public buildings of conſequence are a handſome Congregational church, with an elegant ſteeple and clock, and an alms-houſe, very commodious and pleaſantly ſituated.

Before the deſtruction of this town by the Britiſh in 1775, ſeveral branches of manufactures were carried on to great advantage, ſome of which have been ſince revived; particularly the manufacture of pot and pearl aſhes, ſhip-building, rum, leather in all its branches, ſilver, tin, braſs, and pewter. Three rope-walks have lately been erected in this town, and the increaſe of its houſes, population, trade, and navigation, have been very great within a few years paſt. This town is a port of entry in conjunction with Boſton. At the head of the neck there is a bridge over Myſtic River which connects Charleſtown with Malden.—*ib.*

CHARLESTOWN, a village in Berkley co. Virginia, ſituated on the great road leading from Philadelphia to Wincheſter; 8 miles from Shepherdſtown, and 20 from Wincheſter.

CHARLESTOWN, a townſhip in Waſhington co. Rhode-Iſland ſtate, having the Atlantic ocean on the ſouthward, and ſeparated from Richmond on the northward by Charles-river, a water of Pawcatuck. Some of its ponds empty into Pawcatuck River, others into the ſea. It is 19 miles N. W. of Newport, and contains 2022 inhabitants, including 12 ſlaves.

A few years ago there were about 500 Indians in the ſtate; the greater part of them reſided in this townſhip. They are peaceable and well diſpoſed to government, and ſpeak the Engliſh language.—*ib.*

CHARLESTOWN, the only town in the iſland of Nevis, one of the Caribbees, belonging to Great-Britain. In it are large houſes and well furniſhed ſhops, and it is defended by Charles fort. In the pariſh of St John, on the S. ſide of the town, is a large ſpot of ſulphureous ground, at the upper end of a deep chaſm in the earth, commonly called Sulphur Gut, which is ſo hot as to be felt through the ſoles of one's ſhoes. A ſmall hot river, called the Bath, is thought to proceed from the ſaid gut; and after running half a mile, loſes itſelf in the ſands of the ſea. Black-Rock pond, about a quarter of a mile N. from the town, is milk-warm, owing to the mixture of hot and cold ſprings, yet it yields excellent fiſh; particularly fine eels, ſilver fiſh, and ſlim-guts. A prodigious piece of Nevis mountain falling down in an earthquake, ſeveral years ago, left a large vacuity, which is ſtill to be ſeen. The altitude of this mountain, taken by a quadrant from Charleſtown bay, is ſaid to be a mile and a half perpendicular; and from the ſaid bay to the top, four miles. The declivity from this mountain to the town is very ſteep half way, but afterwards eaſy of aſcent. N. lat. 16. 55. W. long. 62. 42.—*ib.*

CHARLESTOWN, or *Oſtins*, one of the four principal towns in the iſland of Barbadoes.—*ib.*

CHARLETON *Iſland*, or *Charles Iſland*, is ſituated at the bottom of James's bay, in New South Wales, on the coaſt of Labrador, and yields a beautiful proſpect, in ſpring, to thoſe who are near it, after a voyage of 3 or 4 months in the moſt uncomfortable ſeas on the globe, and that by the vaſt mountains of ice in Hudſon bay and ſtraits. The whole iſland, ſpread with trees and branches, exhibits, as it were, a beautiful green tuft. The air even at the bottom of the bay, though in 51 degrees, a latitude nearer the ſun than London, is exceſſively cold for nine months, and very hot the other three, except on the blowing of a N. W. wind. The ſoil on the E. ſide, as well as the W. bears all kinds of grain; and ſome fruits, gooſeberries, ſtrawberries, and dewberries, grow about Rupert's bay. N. lat. 52. 30. W. long. 82.—*ib.*

CHARLETON, a townſhip in Saratoga co. New-York. By the ſtate cenſus of 1796, 268 of its inhabitants were electors.—*ib.*

CHARLETON, a townſhip in Worceſter co. Maſſachuſetts, incorporated in 1754, and until then, formed the weſterly part of Oxford. It is 60 miles S. W. of Boſton, 15 S. W. of Worceſter, and contains 1965 inhabitants. Quinebaugh River forms ſome of its rich intervale lands, and furniſhes excellent mill ſeats for this, and many adjacent towns.—*ib.*

CHARLOTTE *Fort*, in S. Carolina, is ſituated on the point of land where Tugeloo and Broad rivers, uniting their waters, form Savannah River. According to Bartram, it is one mile below Fort James, Dartmouth. N. lat. 34. W. long. 82. 35.—*ib.*

CHARLOTTE *Haven*, lies at the mouth of Charlotte River in E. Florida; having Carlos bay on the S. and Rock Point on the northward. N. lat. 27. W. long. 82. 40. Charlotte River is fed by Spiritu Santo Lagoon, which communicates, by Delaware River with Chatham or Punjo bay, which is 90 miles S. E. from Charlotte Haven.—*ib.*

CHARLOTTE, a conſiderable townſhip on the E. ſide of Lake Champlain, and the S. weſternmoſt in Chittenden co. Vermont. Shelburne on the N. ſeparates this town from Burlington. It contains 635 inhabitants. Split Rock, in Lake Champlain, lies off this town.

CHARLOTTE *Co.* in Virginia, lies S. W. of Richmond, on the head waters of Staunton River, and contains 10,078 inhabitants, including 4,816 ſlaves. The court-houſe is 21 miles S. S. W. of Prince Edward court-houſe, and 379, about the ſame courſe, from Philadelphia.—*ib.*

CHARLOTTEBURG, a town in Brunſwick co. N. Carolina. It ſtands on an iſland, and has an inlet and ſound of the ſame name, a little S. of it.—*ib.*

CHARLOTTE, or *Charlotteſville*, a poſt-town in Saliſbury diſtrict, N. Carolina, and chief town of Mecklenburg co. ſituated on Steel creek, which joins the Sugaw, and falls into Catabaw River about 10 miles N. of the S. Carolina boundary, and 44 S. of Saliſbury. Here are about 40 houſes, a court-houſe and gaol. —*ib.*

CHARLOTTESVILLE, the capital of Albemarle co. in Virginia, lies on the poſt road from Richmond to Danville, in Kentucky, 86 miles W. N. W. of the former, and 557 eaſtward of the latter, and 40 S. E. by E. of Staunton. It contains about 45 houſes, a court-houſe and a goal, ſituated about half a mile N. from a water of Rivanna river.—*ib.*

CHARLOTTE *Town*, the capital of the iſland of St John's, in the gulf of St Lawrence. Alſo, the name of a town on the S. W. ſide of the iſland of Dominica, in the W. Indies; and ſituated on the S. ſide of a deep bay.—*ib.*

CHARLOTIA, a town on the E. ſhore of St John's River, Eaſt Florida, where that river is about half a mile wide. It was founded by Den. Rolle, Eſq. and is ſituated on a high bluff, 15 or 20 feet perpendicular from the river; and is in length half a mile, or more. The aborigines of America had a very great town in this place, as appears from the great tumuli and conical mounts of earth and ſhells, and other traces of a ſettlement which yet remain. The river, for near 12 miles above Charlotia, is divided into many channels by a number of iſlands.—*ib.*

CHARTRES, a fort which was built by the French, on the eaſtern ſide of the Miſſiſſippi, 3 miles northerly of *La Praire du Rocher*, or the Rock Meadows, and 12 miles northerly of St Genevieve, on the weſtern ſide of that river. It was abandoned in 1772, being untenable by the conſtant waſhings of the Miſſiſſippi in high floods. The village ſouthward of the fort was very inconſiderable in 1778. A mile above this is a village ſettled by 170 warriors of the Piorias and Mitchigamias tribes of Illinois Indians, who are idle and debauched.—*ib.*

CHATHAM, a maritime townſhip in Barnſtable co. Maſſachuſetts, ſituated on the exterior extremity of the elbow of Cape Cod, conveniently for the fiſhery; in which they have uſually about 40 veſſels employed. It has 1140 inhabitants, and lies 95 miles S. E. of Boſton.—*ib.*

CHATHAM, a townſhip in Grafton co. New-Hampſhire. It was incorporated in 1767, and in 1790 contained 58 inhabitants.—*ib.*

CHATHAM, a flouriſhing townſhip in Middleſex co. Connecticut, on the eaſtern bank of Connecticut River and oppoſite Middleton city. It was a part of the townſhip of Middleton till 1767.—*ib.*

CHATHAM, a townſhip in Eſſex co. N. Jerſey, is ſituated on Paſſaic River, 13 miles W. of Elizabethtown, and nearly the ſame from Newark.—*ib.*

CHATHAM, a townſhip in Columbia co. New-York. By the ſtate cenſus of 1796, 380 of its inhabitants were electors.—*ib.*

CHATHAM *Co.* in Hillſborough diſtrict, N. Carolina, about the centre of the ſtate. It contains 9221 inhabitants, of whom 1632 are ſlaves. Chief town, Pittſburg. The court-houſe is a few miles W. of Raleigh, on a branch of Cape Fear river.—*ib.*

CHATHAM, a town of S. Carolina, in Cheraws diſtrict, ſituated in Cheſterfield co. on the W. ſide of Great Pedee River. Its ſituation, in a highly cultivated and rich country, and at the head of a navigable river, bids fair to render it a place of great importance. At preſent it has only about 30 houſes, lately built.—*ib.*

CHATHAM *Co.* in the lower diſtrict of Georgia, lies in the N. E. corner of the ſtate, having the Atlantic ocean E. and Savannah river N. E. It contains 10,769 inhabitants, including 8,201 ſlaves. The chief town is Savannah, the former capital of the ſtate.—*ib.*

CHATHAM, or *Punjo bay*, a large bay on the W. ſide of the S. end of the promontory of E. Florida. It receives North and Delaware rivers.—*ib.*

CHATHAM *Houſe*, in the territory of the Hudſon bay company, N. lat. 55. 23. 40. W. long. from Greenwich 98.—*ib.*

CHATA-HATCHI, or *Hatchi*, is the largeſt river which falls into St Roſe's bay in W. Florida. It is alſo called Pea river, and runs from N. E. entering the bottom of the bay through ſeveral mouths; but ſo ſhoal that only a ſmall boat or canoe can paſs them. Mr Hutchins aſcended this river about 25 leagues, where there was a ſmall ſettlement of Couſſac Indians. The ſoil and timber on the banks of the river reſemble very much thoſe of Eſcambia.

CHATAUCHE, or *Chatahuthe*, a river in Georgia. The northern part of Appalachicola river bears this name. It is about 30 rods wide, very rapid, and full of ſhoals. The lands on its banks are light and ſandy, and the clay of a bright red. The Lower Creeks are ſettled in ſcattering clans and villages from the head to the mouth of this river. Their huts and cabins, from the high colour of the clay, reſemble cluſters of new-burned brick kilns. The diſtance from this river to the Talapooſe River is about 70 miles, by the war-path, which croſſes at the falls, juſt above the town of the Tuckabatches.—*ib.*

CHATAUGHQUE *Lake*, in Ontario co. New-York, is about 18 miles long, and 3 broad. Conewango River which runs a S. S. E. courſe, connects it with Alleghany River. This lake is conveniently ſituated for a communication between lake Erie and the Ohio; there being water enough for boats from fort Franklin on the Alleghany to the N. W. corner of this lake; from thence there is a portage of 9 miles to Chataughque harbor on lake Erie, over ground capable of being made a good waggon road. This communication was once uſed by the French.—*ib.*

CHAUMETTE (Pierre Gaſparine), though a man of talents and an author, would hardly have deſerved a place in this work, did not his life and the manner of his death hold out an awful warning againſt thoſe principles which produced the overthrow of ſocial order in France.

He was a native of the town of Nevers, in the Orleanois; and as he roſe to the office of recorder in Paris, few men excited more attention in France for a time, or had a more hateful taſk to perform, during the moſt tragical part of the revolution, than Chaumette. He had been bred to the ſea; but not reliſhing that life, and failing to obtain expected preferment therein, he quitted it, and lived by the uſe of his pen, which he certainly knew how to manage more to his profit than the compaſs. He could, however, ſpeak better, and more fluently, than he could write. He had alſo been employed as a librarian and amanuenſis to a dignitary of the church, in the dioceſe of Nivernois; but at the commencement of the troubles in France, he was actually a clerk to an attorney, and occaſionally wrote for the newſpapers, as well as trifles for the ſtage. He was one of the chief diſciples of Camille Deſmoulins, and among the firſt who put the tri-coloured cockade in his hat juſt before the taking of the Baſtille. He greatly out-ran that apoſtle in zeal for the new faith; for when Camille was compoſing the firſt number of his *Vieux Cordelier*, with the hope of tranquilliſing the overheated imaginations of the leaders of that great event, and tempering the public rage againſt the real or ſuppoſed enemies of the new order of things, Chaumette was ſtill farther inflaming it, and directing it in vengeance againſt particular individuals. It was Chaumette that inſtigated the commune of Paris to demand the trial of the queen, and he was of the committee which prepared the charges and regulated the evidence againſt that ill-fated woman. He was himſelf a witneſs too againſt her at the revolutionary tribunal, and undertook to reprimand M. la Tour Dupin, lately war miniſter to Louis XVI. for not expoſing thoſe parts of Antoinette's conduct, which, it was inſiſted on, he was privy to or acquainted with.

The moſt infamous part of Chaumette's conduct on that occaſion was his accuſing the queen of an inceſtuous connection with her ſon. Even the horrid tribunal was ſhocked at this inſinuation, of which the author became inſtantly the object of almoſt univerſal abhorrence; and Robeſpierre himſelf, under whoſe auſpices Chaumette was believed to act, grew outrageous when he was told of a charge ſo ſcandalouſly abſurd. "The fool (exclaimed he) was it not enough that he had proved her a Meſſalina, but he muſt make her an Agrippina too!" Of proof indeed there was not much; and the ſevereſt enemy of the beautiful Antoinette, if his mind be not wholly warped by prejudice, will admit, that by theſe brethren in iniquity ſhe was murdered under the form of a revolutionary trial.

Robeſpierre had ſenſe enough to ſee that this abominable conduct of Chaumette would hurt the cauſe in which they were both embarked; and for that reaſon he never forgave him, though he allowed the zeal to continue to operate on inferior objects, till it whelmed the zealot himſelf in ruin. Chaumette had credit now with none but the very *ſcum* of the revolution; and ſuch recrementitious matter will always be thrown off in national ebullitions of this kind.

Robeſpierre was at this time in the very zenith of his power, yet Chaumette moved ſuch a propoſition in the full commune, as gave reaſon to many to believe that he would ſet up as his rival in the city. This daring motion was for uniting all the heads of the 48 ſections of Paris in one council; a meaſure that would have ſuperſeded the force of the legiſlature itſelf, if not its authority. This was a project, conceived in common with the famous Hebert, Momora, and Mazuel, and would have been aided in its execution by the daring Rouſin, who at that time commanded a body of the *armeé revolutionaire*.

How far Robeſpierre was appriſed of or approved the ſcheme, does not appear; many ſhrewd obſervers of what was paſſing, ſeemed ſatisfied that it was to have been only a prelude "to the ſwelling act" that was to follow, when the hero of the piece was to have been in full play. The majority of the convention ſaw through the veil which covered the workings of the plot, and anticipated their own danger, ſhould it be carried into effect. They, therefore, without loſs of time, annulled the proceedings already had in it, and declared all to be rebels who ſhould perſiſt therein. Chaumette appeared to put a good face on the correction. He told the commune, on its next meeting, that his propoſition muſt be relinquiſhed; for that the convention, with a voice paternal, though ſevere, had ſtamped with

nullity

with all our manufactures: The glaſs-blower, the potter, the ſmith, and every other worker in metals, the tanner, the ſoap-maker, the dyer, the bleacher, are really practical chemiſts; and the moſt eſſential improvements have been introduced into all theſe arts by the progreſs which chemiſtry has made as a ſcience. Agriculture can only be improved rationally, and certainly by calling in the aſſiſtance of chemiſtry; and the advantages which medicine has derived from the ſame ſource are too obvious to be pointed out.

3 Arrangement.

It is evident from the definition of chemiſtry that it muſt conſiſt in a hiſtory of the ſimple ſubſtances which enter into the compoſition of bodies, in an inveſtigation of the manner in which theſe ſubſtances combine, and in a deſcription of the properties of the compounds which they form. And this is the arrangement which we mean to purſue; reſerving to ourſelves, however, the liberty of deviating a little from it, whenever it may appear neceſſary for the ſake of perſpicuity. All our claſſifications are in fact artificial; nature does not know them, and will not ſubmit to them. They are uſeful, however, as they enable us to learn a ſcience ſooner, and to remember it better; but if we mean to derive theſe advantages from them, we muſt renounce a rigid adherence to arbitrary definitions, which nature diſclaims.

We ſhall begin by an account of the ſimpleſt bodies, and proceed gradually to thoſe which are more compound. By *ſimple bodies*, we do not mean what the ancient philoſophers called the *elements of bodies*, but merely ſubſtances, which have not yet been decompounded. Very poſſibly the bodies which we reckon ſimple may be real compounds; but till this has actually been proved, we have no right to ſuppoſe it. Were we acquainted with all the elements of bodies, and with all the combinations of which theſe elements are capable, the ſcience of chemiſtry would be as perfect as poſſible; but at preſent this is very far from being the caſe.

We ſhall divide this article into four parts. The *firſt* part ſhall treat of thoſe bodies which are at preſent conſidered as ſimple; the *ſecond*, of thoſe bodies which are formed by the union of two ſimple bodies, and which for want of a better word we ſhall call *compound bodies;* the *third*, of thoſe bodies which are formed by the union of two compound bodies; and the *fourth*, of bodies ſuch as they are preſented to us by nature in the mineral, vegetable, and animal kingdoms.

PART I. OF SIMPLE BODIES. (1)

4 Claſſes of ſimple bodies.

ALL the bodies which are at preſent reckoned ſimple, becauſe they have never been decompounded, may be reduced into ſix claſſes.

1. Oxygen,
2. Simple combuſtibles,
3. Metals,
4. Earths,
5. Caloric,
6. Light.

Theſe ſhall form the ſubjects of the ſix following chapters.

CHAP. I. *Of* OXYGEN.

Plate. XVIII.

5 Method of procuring oxygen.

TAKE a quantity of nitre, or ſaltpetre as it is alſo called, and put it into a gun barrel A (fig. 1.), the touch-hole of which has been previouſly cloſed up with metal. This barrel is to be bent in ſuch a manner, that while the cloſe end, in which the nitre lies, is put into the fire E, the open end may be plunged below the ſurface of the water, with which the veſſel B is filled. At the ſame time, the glaſs jar, D, previouſly filled with water, is placed on the ſupport C, lying at the bottom of the veſſel of water B, ſo as to be exactly over the open end of the gun barrel A. As ſoon as the nitre becomes hot, it emits a quantity of air, which iſſuing from the end of the gun barrel, aſcends to the top of the glaſs jar D, and gradually diſplaces all the water. The glaſs jar D then appears to be empty, but is in fact filled with air. It may then be removed in the following manner; Slide it away a little from the gun barrel and the ſupport, and then dipping any flat diſh into the water below it, raiſe it on it, and bear it away. The diſh muſt be allowed to retain a quantity of water in it, (ſee fig. 2.) Another jar may then be filled with air in the ſame manner; and this proceſs may be continued either till the nitre ceaſes to give out air, or till as many jarfuls have been obtained as are required. This method of obtaining and confining air was firſt invented by Dr Mayow, and afterwards much improved by Dr Hales. All the airs obtained by this or any other proceſs, or, to ſpeak more properly, all the airs differing from the air of the atmoſphere, have, in order to diſtinguiſh them from it, been called *gaſes*, and this name we ſhall afterwards employ.

6 Diſcovere by Prieſtl and Schee

The gas which we have obtained by the above proceſs was diſcovered by Dr Prieſtley on the 1ſt of Auguſt 1774, and called by him *dephlogiſticated air*. Mr Scheele of Sweden diſcovered it in 1775, without any previous knowledge of what Dr Prieſtley had done: he gave it the name of *empyreal air*. Condorcet, ſo conſpicuous during the French revolution, gave it firſt the name of *vital air;* and Mr Lavoiſier afterwards called it *oxygen gas;* a name which is now generally received, and which we ſhall adopt.

Oxygen gas may be obtained likewiſe by the following proceſs:

7 Another method.

D (in fig. 3.) repreſents a wooden trough, the inſide of which is lined with lead or tinned copper. AB is a ſhelf running along the inſide of it, about three inches from the top. C is the cavity of the trough, which ought to be a foot deep. It is to be filled with water at leaſt an inch above the ſhelf AB. In the body of the trough, which may be called the ciſtern, the jars deſtined to hold gas are to be filled with water, and then to be lifted, and placed inverted upon the ſhelf at B, with their edges a little over it. This trough, which was invented by Dr Prieſtley, has been called by the French chemiſts the *pneumato chemical*, or ſimply *pneumatic* apparatus, and is extremely uſeful in all experiments in which gaſes are concerned. Into the glaſs veſſel E put a quantity of the black oxyd (A) of manganeſe in powder, and pour over it as much of that liquid which in commerce is called *oil of vitriol*, and in chemiſtry *ſulphuric acid*, as will ſomewhat more than cover it. Then inſert into the mouth of the veſſel the glaſs tube F, ſo cloſely that no air can eſcape except through the tube. This may be done by covering the joining with a paſte made of wheat flour and water, or any other *lute*, as ſubſtances uſed for ſimilar purpoſes are called. The end of the tube C is then to be plunged into the pneumatic apparatus D and the jar G, previouſly filled with water, to be placed over it on the ſhelf. The whole apparatus being fixed in that ſituation, the glaſs veſſel E is to be heated by means of a lamp or a candle. A great quantity of oxygen gas ruſhes along the tube F, and fills the jar G. As ſoon as the jar is filled, it may be ſlid to another part of the ſhelf, and other jars ſubſtituted in its place, till as much gas has been obtained as is wanted.

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(1) The writer of the notes ſigned T. P. S. conſiders himſelf reſponſible for no other errors contained in this ſyſtem of chemiſtry than thoſe contained in his own notes. From a number of circumſtances he was under the neceſſity of reading this work ſo curſorily, that probably many deductions which on more mature conſideration he might have objected to, may have paſſed unnoticed. T. P. S.

8 operties oxygen. 1. Oxygen gas is colourleſs, and inviſible like common air. Like it too, it is elaſtic, and capable of indefinite expanſion and compreſſion.

9 pports ne, 2. If a lighted taper be let down into a jar of oxygen gas, it burns with ſuch ſplendor that the eye can ſcarcely bear the glare of light, and at the ſame time produces a much greater heat than when burning in common air. It is well known that a candle put into a well cloſed jar filled with common air is extinguiſhed in a few ſeconds. This is the caſe alſo with a candle incloſed in oxygen gas; but it burns much longer in an equal quantity of that gas than of common air.

10 d life. 3. It was proved long ago by Boyle, that animals cannot live without air, and by Mayow that they cannot breathe the ſame air for any length of time without ſuffocation. Dr Prieſtley and ſeveral other philoſophers have ſhewn us, that animals live much longer in the ſame quantity of oxygen gas than of common air. Count Morozzo placed a number of ſparrows, one after another, in a glaſs bell filled with common air, and inverted over water.

	H.	M.
The firſt ſparrow lived	3	0
The ſecond	0	3
The third	0	1

He filled the ſame glaſs with oxygen gas, and repeated the experiment.

	H.	M.
The firſt ſparrow lived	5	23
The ſecond	2	10
The third	1	30
The fourth	1	10
The fifth	0	30
The ſixth	0	47
The ſeventh	0	27
The eighth	0	30
The ninth	0	22
The tenth	0	21

He then put in two together; the one died in 20 minutes, but the other lived an hour longer.

11 Exiſts in the atmoſphere. 4. Atmoſpherical air contains about 27 parts in the hundred of oxygen gas. This was firſt diſcovered by Scheele. It has been proved by a great number of experiments, that no ſubſtance will burn in common air previouſly deprived of all the oxygen gas which it contained; but combuſtibles burn with great ſplendor in oxygen gas, or in other gaſes to which oxygen gas has been added. Oxygen gas, then, is abſolutely neceſſary for combuſtion.

5. It has been proved alſo, by many experiments, that no breathing animal can live for a moment in any air or gas which does not contain oxygen mixed with it. Oxygen gas then is abſolutely neceſſary for reſpiration.

6. When ſubſtances are burnt in oxygen gas, or in any other gas containing oxygen, if the air be examined after the combuſtion, a great part of the oxygen will be found to have diſappeared. If charcoal, for inſtance, be burnt in oxygen gas, there will be found, inſtead of part of the oxygen, another very different gas, known by the name of carbonic acid gas. Exactly the ſame thing takes place when air is reſpired by animals; part of the oxygen gas diſappears, and its place is occupied by ſubſtances poſſeſſed of very different properties. Oxygen gas then undergoes ſome change during combuſtion, as well as the bodies which have been burnt; and the ſame obſervation applies alſo to reſpiration (B).

12 Its ſpecific gravity. 7. The ſpecific gravity of oxygen gas, as determined by Mr Kirwan*, is 0,00135, that of water being 1,0000, as is always the caſe when ſpecific gravity is mentioned abſolutely. It is therefore 740 times lighter than the ſame bulk of water. Its weight to atmoſpherical air is as 1103 to 1000: 116 cubic inches of oxygen gas weigh 39,03 grains troy, 116 cubic inches of common air, 35,38 grains.

* On *Phlogiſton*, ſect. i.

13 *Affinity* explained. 8. Oxygen is capable of combining with a great number of bodies, and forming compounds. As the combination of bodies is of the utmoſt importance in chemiſtry,

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(A) This ſubſtance ſhall be afterwards deſcribed. It is now very well known in Britain, as it is in common uſe with bleachers and ſeveral other manufacturers.

(B) Mayow had in the laſt century made conſiderable progreſs towards the diſcovery of oxygen gas. He knew that only a part of the air ſupported combuſtion: This part he called *particulæ igneo-aereæ*. He knew that this part was contained in nitre: Pars nitri aerea nihil aliud quam particulæ ejus igneo-aereæ eſt." He adds, "At non eſt eſtimandum pabulum igneo-aereum ipſum aerem eſſe, ſed tantum partem ejus majus activam ſubtilemque. Quippe lucerna vitro incluſa expirat cum tamen copia aeris ſatis ampla in eodem continetur." He knew alſo that it was this part of the air which was uſeful in reſpiration. After mentioning ſeveral experiments to prove this, he adds, "Ex dictis certo conſtat animalia reſpirando particulas quaſdam vitales eaſque elaſticas ab aere haurire." See his *Tractatus quinque Medico-Phyſici*, p. 12. and 106.—He knew alſo that this part of the air was neceſſary to combuſtion: "Et tamen certo conſtat, particulas nitro-aereas non minus quam ſulphureas ad ignem conflandum neceſſareas eſſe." *Ibid.* p. 26.

16 Properties of ſulphur.

Sulphur is a hard brittle ſubſtance, commonly of a yellow colour, without any ſmell, and of a weak though perceptible taſte.

It is a non-conductor of electricity, and of courſe becomes electric by friction.

If a conſiderable piece of ſulphur be expoſed to a ſudden though gentle heat, by holding it in the hand, for inſtance, it breaks to pieces with a crackling noiſe†.

Its ſpecific gravity is 1,990.

When heated to the temperature of 185° of Fahrenheit, it melts and becomes very fluid. If the temperature be ſtill farther increaſed, the fluidity diminiſhes; but when the ſulphur is then carried from the fire and allowed to cool, it becomes as fluid as ever before it congeals‡.

17 Flowers of ſulphur.

When ſulphur is heated to the temperature of 170°, it riſes up in the form of a fine powder, which may be eaſily collected in a proper veſſel. This powder is called *flowers of ſulphur*. When ſubſtances fly off in this manner on the application of a moderate heat, they are called *volatile;* and the proceſs itſelf, by which they are raiſed, is called *volatilization.*

Sulphur undergoes no change by being allowed to remain expoſed to the open air.

When thrown into water, it does not melt, as common ſalt does, but falls to the bottom, and remains there unchanged; it is therefore *inſoluble* in water. If, however, it be poured, while in a ſtate of fuſion, into water, it aſſumes a red colour, and retains ſuch a degree of ſoftneſs, that it may be kneaded between the fingers; but it loſes this property in a few days*.

18 Sulphur capable of cryſtallizing.

There are a great many bodies which, after being diſſolved in water or melted by heat, are capable of aſſuming certain regular figures. If a quantity of common ſalt, for inſtance, be diſſolved in water, and that fluid, by the application of a moderate heat, be made to fly off in the form of ſteam; or, in other words, if the water be ſlowly *evaporated,* the ſalt will fall to the bottom of the veſſel in cubes. Theſe regular figures are called *cryſtals.* Now ſulphur is capable of cryſtallizing. If it be melted, and as ſoon as its ſurface begins to congeal, the liquid ſulphur beneath be poured out, the internal cavity will exhibit long needle-ſhaped cryſtals of an octahedral figure. This method of cryſtallizing ſulphur was contrived by Rouelle.

19 Converted by combuſtion into an acid.

When ſulphur is heated to the temperature of 302° in the open air, it takes fire ſpontaneouſly, and burns with a pale blue flame, and at the ſame time emits a great quantity of fumes of a very ſtrong ſuffocating odour. When heated to the temperature of 570°, or a little higher, it burns with a bright white flame, and at the ſame time emits a vaſt quantity of fumes. If the heat be continued long enough, the ſulphur burns all away without leaving any aſhes or *reſiduum.* If the fumes be collected, they are found to conſiſt entirely of *ſulphuric acid.* By combuſtion, then, ſulphur is converted into an acid. This fact was known ſeveral centuries ago, but no intelligible explanation was given of it till the time of Stahl. That chemiſt undertook the taſk; and founded on his experiments a theory ſo exceedingly ingenious, and ſupported by ſuch a vaſt number of facts, that it was in a very ſhort time adopted with admiration by all the philoſophic world, and contributed not a little to raiſe chemiſtry to that rank among the ſciences from which the ridiculous pretenſions of the early chemiſts had excluded it.

20 Stahl's explanation of this

According to Stahl, there is only one ſubſtance in nature capable of combuſtion, which therefore he called Phlogiston; and all thoſe bodies which can be ſet on fire contain leſs or more of it. Combuſtion is merely the ſeparation of this ſubſtance. Thoſe bodies which contain none of it are of courſe incombuſtible. All combuſtibles, except thoſe which conſiſt of pure phlogiſton (if there be any ſuch), are compoſed of an incombuſtible body and phlogiſton united together. During combuſtion the phlogiſton flies off, and the incombuſtible body remains behind. Now when ſulphur is burnt, the ſubſtance which remains is ſulphuric acid, an incombuſtible body. Sulphur therefore is compoſed of ſulphuric acid and phlogiſton.

To eſtabliſh this theory completely, it was neceſſary to ſhew that ſulphur could be actually made by combining ſulphuric acid and phlogiſton; and this alſo Stahl undertook to perform. *Sulphat of potaſs* is a ſubſtance compoſed of ſulphuric acid and potaſs (D), and *charcoal* is a combuſtible body, and therefore, according to the theory of Stahl, contains phlogiſton: when burnt, it leaves a very inconſiderable reſiduum, and conſequently contains hardly any thing elſe than phlogiſton. He melted together in a crucible a mixture of *potaſs* and *ſulphat of potaſs,* ſtirred into it one-fourth part by weight of pounded charcoal, covered the crucible with another inverted over it, and applied a ſtrong heat to it. He then allowed it to cool, and examined its contents. The charcoal had diſappeared, and there only remained in the crucible a mixture of potaſs and ſulphur combined together, and of a darker colour than uſual, from the reſiduum of the charcoal. Now there were only three ſubſtances in the crucible at firſt, potaſs, ſulphuric acid, and charcoal: two of theſe have diſappeared, and *ſulphur* has been found in their place. Sulphur then muſt have been formed by the combination of theſe two. But charcoal conſiſts of phlogiſton and a very ſmall reſiduum, which is ſtill found in the crucible. The ſulphur then muſt have been formed by the combination of ſulphuric acid and phlogiſton. This ſimple and luminous explanation appeared ſo ſatisfactory, that the compoſition of ſulphur was long conſidered as one of the beſt demonſtrated truths in chemiſtry.

21 Unſatisfactory.

There are two facts, however, which Stahl either did not know or did not ſufficiently attend to, neither of which were accounted for by his theory. The firſt is, that ſulphur will not burn if air be completely excluded; the ſecond, that ſulphuric acid is heavier than the ſulphur from which it was produced.

To account for theſe, or facts ſimilar to theſe, ſucceeding chemiſts refined upon the theory of Stahl, deprived his phlogiſton of *gravity,* and even aſſigned it a principle of *levity.* Still, however, the neceſſity of the contact of air remained unexplained. At laſt Mr Lavoiſier, who had already diſtinguiſhed himſelf by the extenſiveneſs of his views, the accuracy of his experiments,

† Fourcroy.

‡ Dr Black.

* Fourcroy.

(D) The nature of *potaſs* ſhall afterwards be explained. It is the *potaſh* well known in commerce in a ſtate of purity.

22 Real explanation by Lavoiſier.

and the preciſion of his reaſoning, undertook the examination of this ſubject, and his experiments were publiſhed in the Memoirs of the Academy of Sciences for 1777. He put a quantity of ſulphur into a large glaſs veſſel filled with air, which he inverted into another veſſel containing mercury, and then ſet fire to the ſulphur by means of a burning glaſs. It emitted a blue flame, and gave out thick vapours, but was very ſoon extinguiſhed, and could not be again kindled. There was, however, a little ſulphuric acid formed, which was a good deal heavier than the ſulphur which had diſappeared; there was alſo a diminution in the air of the veſſel proportional to this increaſe of weight. The ſulphur, therefore, during its converſion into an acid, muſt have abſorbed part of the air. He then put a quantity of ſulphuret of iron, which conſiſts of ſulphur and iron combined together, into a glaſs veſſel full of air, which he inverted over water (E). The quantity of air in the veſſel continued diminiſhing for eighteen days, as was evident from the aſcent of the water to occupy the ſpace which it had left; but after that period no farther diminution took place. On examining the ſulphuret, it was found ſomewhat heavier than when firſt introduced into the veſſel, and the air of the veſſel wanted preciſely the ſame weight. Now this air had loſt all its oxygen; all the oxygen of the air in the veſſel muſt therefore have entered into the ſulphuret. Part of the ſulphur was converted into ſulphuric acid; and as all the reſt of the ſulphuret was unchanged, the whole of the increaſe of weight muſt have been owing to ſomething which had entered into that part of the ſulphur which was converted into acid. This ſomething we know was oxygen. Sulphuric acid therefore muſt be compoſed of ſulphur and oxygen; for as the original weight of the whole contents of the veſſel remained exactly the ſame, there was not the ſmalleſt reaſon to ſuppoſe that any ſubſtance had left the ſulphur.

It is impoſſible, then, that ſulphur can be compoſed of ſulphuric acid and phlogiſton, as Stahl ſuppoſed; ſince ſulphur itſelf enters as a part into the compoſition of that acid. There muſt therefore have been ſome want of accuracy in the experiment by which Stahl proved the compoſition of ſulphur, or at leaſt ſome fallacy in his reaſonings; for it is impoſſible that two contradictory facts can both be true. Upon examining the potaſs and ſulphur produced by Stahl's experiment, we find them to be conſiderably lighter than the charcoal, ſulphuric acid, and potaſs originally employed. Something therefore has made its eſcape during the application of the heat. And if the experiment be conducted in a cloſe veſſel, with a pneumatic apparatus attached to it, a quantity of gas will be obtained exactly equal to the weight which the ſubſtances operated on have loſt; and this weight conſiderably exceeds that of all the charcoal employed. This gas is *carbonic acid gas*, which is compoſed of charcoal and oxygen, as will afterwards appear. We now perceive what paſſes in this experiment: Charcoal has a ſtronger affinity for oxygen at a high temperature than ſulphur has. When charcoal therefore is preſented to ſulphuric acid in that temperature, the oxygen of the acid combines with it, they fly off in the form of carbonic acid gas, and the ſulphur is left behind.

The combuſtion of ſulphur, then, is nothing elſe than the act of its combination with oxygen; and, for any thing which we know to the contrary, it is a ſimple ſubſtance.

23 Affinities of ſulphur.

The affinities of ſulphur, according to Bergman, are as follows:

Lead,
Tin,
Silver,
Mercury,
Arſenic,
Antimony,
Iron,
Fixed alkalies,
Ammonia,
Barytes,
Lime,
Magneſia,
Phoſphorus?
Oils,
Ether,
Alcohol.

SECT. II. *Of Phoſphorus.*

24 Production of phoſphorus.

LET a quantity of bones be burnt, or, as it is termed in chemiſtry, *calcined*, till they ceaſe to ſmoke, or to give out any odour, and let them afterwards be reduced to a fine powder. Put this powder into a glaſs veſſel, and pour ſulphuric acid on it by little at a time, till farther additions do not cauſe any extrication of air bubbles (F). Dilute the mixture with a good deal of water, agitate it well, and keep it hot for ſome hours; then paſs it through a filtre. Evaporate the liquid ſlowly till a quantity of white powder falls to the bottom. This powder muſt be ſeparated by filtration, and thrown away. The evaporation is then to be reſumed; and whenever any white powder appears, the filtration muſt be repeated in order to ſeparate it. During the whole proceſs, what remains on the filtre muſt be waſhed with pure water, and this water added to the liquor. The evaporation is to be continued till all the moiſture diſappears, and nothing but a dry maſs remains. Put this maſs into a crucible, and keep it melted in the fire till it ceaſes to exhale ſulphureous odours; then pour it out. When cold it aſſumes the appearance of a brittle glaſs. Pound this glaſs in a mortar, and mix it with one-third by weight of charcoal duſt. Put this mixture into an earthen ware retort, and apply a receiver containing a little water. Put the retort into a ſand bath, and increaſe the fire till it becomes red hot. A ſubſtance then paſſes into the receiver, which has the appearance of melted wax, and which congeals as it falls into the water of the receiver. This ſubſtance is *phoſphorus.*

25 Its diſcovery.

It was diſcovered by Brandt, a chemiſt of Hamburgh, about the year 1667, while he was employed in attempting to extract from human urine, a liquid capable of converting ſilver into gold.*

Kunkel, another German chemiſt, hearing of the diſcovery, was anxious to find out the proceſs, and for that

* *Leibnitz, Melange de Berlin.*

(E) This experiment was firſt made by Scheele, but with a different view.

(F) The copious emiſſion of air bubbles is called in chemiſtry *effervescence.*

that purpoſe aſſociated himſelf with a friend of his named Kraft. But the latter procured the ſecret from the diſcoverer; and expecting by means of it to acquire a fortune, refuſed to give any information to his aſſociate. Vexed at this treachery, Kunkel reſolved to attempt the diſcovery himſelf; and though he knew only that phoſphorus was obtained from urine, proſecuted the inquiry with ſo much zeal, that he ſucceeded, and has been deſervedly conſidered as one of the diſcoverers†.

Boyle likewiſe diſcovered phoſphorus. Leibnitz indeed affirms that Kraft taught Boyle the whole proceſs, and Kraft declared the ſame thing to Stahl. But ſurely the aſſertion of a dealer in ſecrets, and one who had deceived his own friend, on which the whole of this ſtory is founded, cannot be put in competition with the affirmation of a man like Boyle, who was one of the honeſteſt men, as well as greateſt philoſophers, of his age; and he poſitively aſſures us that he made the diſcovery, without being previouſly acquainted with the proceſs‡.

Gahn, a Swediſh chemiſt, diſcovered, in 1769, that phoſphorus was contained in bones||, and Scheele (G) very ſoon after invented a proceſs for obtaining it from them. Phoſphorus is now generally procured in that manner. The proceſs deſcribed in the beginning of this ſection is that of the Dijon academicians: it differs from that of Scheele only in a ſingle particular.

26
ts properties.

Phoſphorus, when pure, is of a clear, tranſparent, yellowiſh colour; but when kept ſome time in water, it becomes opaque, and then has a great reſemblance to white wax. Its conſiſtence is nearly that of wax: it may be cut with a knife, or twiſted to pieces with the fingers. It is inſoluble in water. Its ſpecific gravity is 1,714.

27
Converted by combuſtion

It melts at the temperature of 99°*, and even at 67°* it gives out a white ſmoke, and is luminous in the dark; that is to ſay, it ſuffers a ſlow combuſtion: ſo that it can only be prevented from taking fire by keeping it in a very low temperature, or by allowing it to remain always plunged in water. If air be excluded, it evaporates at 219°, and boils at 554°†. When heated to 122° (H), it burns with a very bright flame, and gives out a great quantity of white ſmoke, which is luminous in the dark; at the ſame time it emits an odour which has ſome reſemblance to that of garlic. It leaves no reſiduum; but when the white ſmoke is collected, it is found to be an *acid*. Stahl conſidered this acid as the muriatic (I). According to him, phoſphorus was compoſed of muriatic acid and phlogiſton, and the combuſtion of it was merely the ſeparation of phlogiſton. He even declared, that to make phoſphorus, nothing more was neceſſary, than to combine muriatic acid and phlogiſton; and that this compoſition was as eaſily accompliſhed as that of ſulphur itſelf‡.

Theſe aſſertions gained implicit credit; and the compoſition and nature of phoſphorus were conſidered as completely underſtood, till Margraf of Berlin publiſhed his experiments in the year 1743. That great man, one of thoſe illuſtrious philoſophers who have contributed ſo much to the rapid increaſe of the ſcience, diſtinguiſhed equally for the ingenuity of his experiments and the clearneſs of his reaſoning, attempted to produce phoſphorus by combining together phlogiſton and muriatic acid; but though he varied his proceſs a thouſand ways, preſented the acid in many different ſtates, and employed a variety of ſubſtances to furniſh phlogiſton, all his attempts failed, and he was obliged to give up the combination as impracticable. On examining the acid produced during the combuſtion of phoſphorus, he found that its properties were very different from thoſe of muriatic acid. It was therefore a diſtinct ſubſtance. The name of *phoſphoric acid* was given to it; and it was concluded that phoſphorus was compoſed of this acid united to phlogiſton.

28
Into phoſphoric acid,

But it was obſerved in 1772 by Morveau*, that phoſphoric acid was heavier than the phoſphorus from which it was produced (K); and Boyle had long before ſhewn that phoſphorus would not burn except when in contact with air. Theſe facts were ſufficient to prove the inaccuracy of the theory concerning the compoſition of phoſphorus; but they remained themſelves unaccounted for, till Lavoiſier publiſhed thoſe celebrated experiments, which threw ſo much light on the nature and compoſition of acids.

He exhauſted a glaſs globe of air by means of an air pump; and after weighing it accurately, he filled it with oxygen gas, and introduced into it 100 grains of phoſphorus. The globe was furniſhed with a ſtop-cock, by which oxygen gas could be admitted at pleaſure. He ſet fire to the phoſphorus by means of a burning glaſs. The combuſtion was extremely rapid, accompanied by a bright flame and much heat. Large quantities of white flakes attached themſelves to the inner ſurface of the globe, and rendered it opaque; and theſe at laſt became ſo abundant, that notwithſtanding the conſtant ſupply of oxygen gas, the phoſphorus was extinguiſhed. The globe, after being allowed to cool, was again weighed before it was opened. The quantity of oxygen employed during the experiment was aſcertained, and the phoſphorus, which ſtill remained unchanged, accurately weighed. The white flakes, which were nothing elſe than pure phoſphoric acid, were found exactly equal to the weights of the phoſphorus and oxygen which had diſappeared during the proceſs. Phoſphoric acid therefore muſt have been formed by the combination of theſe two bodies; for the abſolute weight of all the ſubſtances together was the ſame before and after the proceſs*. It is impoſſible then that phoſphorus can be compoſed of phoſphoric acid and phlogiſton,

29
Which is phoſphorus combined with oxygen.

† Stahl's Three Hun- red Experi- ents.

‡ Boyle Abridged by haw, iii. 74.

|| Bergman's Notes on cheffer.

* Pelletier, Journal de Phyſique, xxxv. 380.

† Ibid. 381.

‡ Three Hundred Experiments.

* Digreſs. Academ. p. 253.

* Lavoiſier's Chemiſtry, Part I. chap. v.

(G) Crell, in his life of Scheele, informs us, that Scheele was himſelf the diſcoverer of the fact. This, he ſays, clearly appears from a printed letter of Scheele to Gahn, who was before looked upon as the diſcoverer. See *Crell's Annals*, Engliſh Tranſ. I. 17.

(H) Morveau, *Enc. Method. Chimie*, art. *Affinité*—According to Nicholſon at 160°. See his *Tranſlation of Chaptal.*

(I) This acid ſhall be afterwards deſcribed.

(K) The ſame obſervation had been made by Margraf, but no attention was paid to it.

phlogiſton, as phoſphorus itſelf enters into the compoſition of that acid(L).

Thus the combuſtion of phoſphorus like that of ſulphur, is nothing elſe than its combination with oxygen: for during the proceſs no new ſubſtance appears except the acid, accompanied indeed with much heat and light.

30
Phoſphorus combines with ſulphur.

Phoſphorus combines readily with ſulphur, as Margraf diſcovered during his experiments on phoſphorus. This combination was afterwards examined by Mr Pelletier. The two ſubſtances are capable of being mixed in different proportions. Seventy-two grains of phoſphorus and nine of ſulphur, when heated in about four ounces of water, melt with a gentle heat. The compound remains fluid till it be cooled down to 77°, and then becomes ſolid. Theſe ſubſtances were combined in the ſame manner in the following proportions:

72 Phoſphor. 18 Sulphur	congeals at	59°
72 Phoſphor. 36 Sulphur	at	50°
72 Phoſphor. 72 Sulphur	at	41°
72 Phoſphor. 216 Sulphur	at	99°

Phoſphorus and ſulphur may be combined alſo by melting them together without any water; but the combination takes place ſo rapidly that they are apt to ruſh out of the veſſel if the heat be not exceedingly moderate.[†]

[†] *Pelletier, Journ. de Phyſ.* xxxv. 382.

Phoſphorus is capable of combining alſo with many other bodies: the compounds produced are called *phoſphurets*.

The affinities of phoſphorus have not yet been aſcertained.

Sect. III. *Of Carbon.*

If a piece of wood be put into a crucible, well covered with ſand, and kept red hot for ſome time, it is converted into a black ſhining brittle ſubſtance, without either taſte or ſmell, well known under the name of *charcoal*. This ſubſtance contains always mixed with it ſeveral earthy and ſaline particles. When freed from theſe impurities it is called *carbon*.

31
Properties of carbon.

Charcoal is inſoluble in water; it is not affected (provided that all air be excluded) by the moſt violent heat which can be applied, excepting only that it is rendered much harder.

New made charcoal abſorbs moiſture with avidity. When heated to a certain temperature, it abſorbs air copiouſly. La Metherie plunged a piece of burning charcoal into mercury, in order to extinguiſh it, and introduced it immediately after into a glaſs veſſel filled with common air. The charcoal abſorbed four times its bulk of air. On plunging the charcoal in water, one-fifth of this air was diſengaged. This air, on being examined, was found to contain a much ſmaller quantity of oxygen than atmoſpherical air does. He extinguiſhed another piece of charcoal in the ſame manner, and then introduced it into a veſſel filled with oxygen gas. The quantity of oxygen gas abſorbed amounted to eight times the bulk of the charcoal; a fourth part of it was diſengaged on plunging the charcoal into water[*]. It appears from the experiments of Sennebier, that charcoal, when expoſed to the atmoſphere abſorbs oxygen gas in preference to *azot*[†], as the other portion of common air is called.

[*] *Journ. de Phyſ.* xxx. 309.

[†] *Ann. de Chim.* iv. 261.

When heated to the temperature of 370°[‡], it takes fire, and provided it has been previouſly freed from the earths and ſalts which it generally contains, it burns without leaving any reſiduum. If this combuſtion be performed in cloſe veſſels filled with oxygen gas inſtead of common air, part of the charcoal and oxygen diſappear, and in their room is found a particular gas exactly equal to them in weight. This gas has the properties of an acid, and is therefore called *carbonic acid gas*. Mr Lavoiſier, to whom we are indebted for this diſcovery, aſcertained, by a number of very accurate experiments, that this gas was compoſed of about 28 parts of carbon and 72 of oxygen[||].

[‡] *Morveau, Encycl. Method.* art. *Affinité*.

32
Converted into an acid.

[||] *Mem. Acad.* 1781, p. 448.

33
Suſceptible of cryſtallization.

Carbon is ſuſceptible of cryſtallization. In that ſtate it is called *diamond*. The figure of the diamond varies conſiderably; but moſt commonly it is a hexagonal priſm terminated by a ſix-ſided pyramid. When pure it is colourleſs and tranſparent. Its ſpecific gravity is from 3,44 to 3,55. It is one of the hardeſt ſubſtances in nature; and as it is not affected by a conſiderable heat, it was for many ages conſidered as incombuſtible. Sir Iſaac Newton, obſerving that combuſtibles refracted light more powerfully than other bodies, and that the diamond poſſeſſed this property in great perfection, ſuſpected, from that circumſtance, that it was capable of combuſtion.(3) This ſingular conjecture was verified in 1694 by the Florentine academicians, in the preſence of Coſmo III. grand duke of Tuſcany. By means of a burning-glaſs, they deſtroyed ſeveral diamonds. Francis I. emperor of Germany, afterwards witneſſed the deſtruction of ſeveral more in the heat of a furnace. Theſe experiments were repeated by Rouelle, Macquer, and D'Arcet, who proved that the diamond was not merely evaporated, but actually burnt, and that if air was excluded it underwent no change.

No attempt, however, was made to aſcertain the product, till Lavoiſier undertook a ſeries of experiments for that purpoſe in 1772. He obtained *carbonic acid gas*. It might be concluded from theſe experiments, that the diamond contains carbon; but it was reſerved for Mr Tennant to ſhow that it conſiſted entirely of that ſubſtance.

Into

(L) The quantity of phoſphorus conſumed was 45 grains
The quantity of oxygen gas - - - 69,375

Weight of the Phoſphoric acid produced 114,375
Phoſphoric acid therefore is compoſed of 100 parts phoſphorus, and 154 oxygen.

(3) It were to be wiſhed that ſome perſon provided with the proper apparatus would experiment on the *refractive* power of the gaſes, and aſcertain if, according to Newton's theory, it bears any relation to their affinity for oxygen. T. P. S.

34
hen it
rms *dia*-
nd.

Into a tube of gold, having one end cloſed and a glaſs tube adapted to the other to collect the product, that gentleman put 2½ grains of diamonds and a quarter of an ounce of nitre (M). This tube was heated ſlowly; the conſequence of which was, that great part of the nitric acid paſſed off before the diamond took fire, and by that means almoſt the whole of the carbonic acid formed during the combuſtion of the diamond remained in the potaſs, for which it has a ſtrong affinity. To aſcertain the quantity of this carbonic acid, he diſſolved the potaſs in water, and added to the ſolution another ſalt compoſed of muriatic acid and lime. Muriatic acid has a ſtronger affinity for potaſs than for lime; it therefore combines with the potaſs, and at the ſame time the lime and carbonic acid unite and fall to the bottom of the veſſel, becauſe they are nearly inſoluble in water. He decanted off the liquor, and put the lime which contained the carbonic acid gas into a glaſs globe, having a tube annexed to it. This globe and tube he then filled with mercury, and inverted into a veſſel containing the ſame fluid. The lime by that means occupied the very top of the tube. It now remained to ſeparate the carbonic acid from the lime, which may be done by mixing it with any acid, as almoſt every other acid has a ſtronger affinity for lime than carbonic acid has. Accordingly on introducing muriatic acid, 10,3 ounce meaſures of carbonic acid gas, or nearly 9,166 grains, were ſeparated. But, according to the experiments of Lavoiſier, this gas is compoſed of 72 parts of oxygen and 28 of carbon; 9,166 grains therefore contain 2,56 grains of carbon, which is almoſt preciſely the weight of the diamond conſumed. It follows, therefore, that it was compoſed of pure carbon.* The difficulty of burning the diamond is owing entirely to its hardneſs. Meſſrs Morveau and Tennant rendered common charcoal ſo hard by expoſing it for ſome time to a violent fire in cloſe veſſels, that it loſt much of its natural tendency to combuſtion, and endured even a red heat without catching fire.†

* *Phil.* *ranſ.* 797, p. 3.

† *Encycl.* *Method.* *himie. art.* cier.

Charcoal poſſeſſes a number of ſingular properties, which render it of conſiderable importance. It is incapable of putrefying or rotting like wood, and is not therefore liable to decay through age. This property has been long known. It was cuſtomary among the ancients to *char* the outſide of thoſe ſtakes which were to be driven into the ground or placed in water, in order to preſerve the wood from ſpoiling. New made charcoal, by being rolled up in cloths which have contracted a diſagreeable odour, effectually deſtroys it. It takes away the bad taint from meat beginning to putrefy, by being boiled along with it. It is perhaps the beſt teeth powder known. Mr Lowitz of Peterſburgh has ſhown, that it may be uſed with advantage to purify a great variety of ſubſtances.

35
arburets.

Carbon unites with a number of bodies, and forms with them compounds known by the name of *carburets*.

Its affinities have not yet been aſcertained.

SECT. IV. *Of Hydrogen.*

36
Method of procuring hydrogen.

PUT into a glaſs veſſel furniſhed with two mouths a quantity of freſh iron filings, quite free from ruſt. Lute into one of theſe mouths the end of a crooked glaſs tube. Inſert the other end of this tube below a glaſs jar filled with water, and inverted into a pneumatic apparatus. Then pour upon the iron filings a quantity of ſulphuric acid, diluted with twice its own weight of water, and cloſe up the mouth of the veſſel. Immediately the iron filings and acid efferveſce with violence, a vaſt quantity of gas is produced, which ruſhes through the tube and fills the jar. This gas is called *hydrogen gas*.(N)

It was obtained by Dr. Mayow and by Dr Hales from various ſubſtances, and had been known long before in mines under the name of the *fire damp*. Mr Cavendiſh * was the firſt who examined its properties with attention. They were afterwards more fully inveſtigated by Prieſtley, Scheele, and Fontana.

* *Phil. Tran.* 1766.

37
Its properties.

Hydrogen, like *air*, is inviſible and elaſtic, and capable of indefinite compreſſion and dilatation.

Its ſpecific gravity differs according to its purity. Kirwan found it 0,00010†; Lavoiſier 0,000094‡, or about 12 times lighter than common air.

All burning ſubſtances are immediately extinguiſhed by being plunged into this gas. It is incapable therefore of ſupporting combuſtion.

† *On Phlogiſton*, ſect. Iſt.

‡ *Lavoiſier's Chemiſtry, Appendix.*

Animals, when they are obliged to breathe it, die almoſt inſtantaneouſly. Scheele indeed found that he could breathe it for ſome time without inconvenience ‡; but Fontana, who repeated the experiment, diſcovered that this was owing to the quantity of common air contained in the lungs when he began to breathe; for on expiring as ſtrongly as poſſible before drawing in the hydrogen gas, he could only make three reſpirations, and even theſe three produced extreme feebleneſs and oppreſſion about the breaſt §.

‡ *Scheele on Fire.*

§ *Jour. de Phyſ.* xv. 99.

If a phial be filled with hydrogen gas, and a lighted candle be brought to its mouth, the gas will take fire, and burn gradually till it is all conſumed. If hydrogen and oxygen gas be mixed together and kindled, they burn inſtantaneouſly, and produce an exploſion like gunpowder. The ſame effect follows when a mixture of hydrogen gas and atmoſpherical air is kindled, but the exploſion is leſs violent. Hydrogen gas will not burn except in contact with oxygen gas, nor will it burn even in contact with oxygen gas, unleſs a red heat be applied to it. If 85 parts by weight of oxygen gas, and 15 of hydrogen gas, be mixed together, and ſet on fire in a cloſe veſſel, they diſappear, and in their place there is found a quantity of water exactly equal to them in weight. This water muſt be compoſed of theſe two gaſes; for it did not previouſly exiſt in the veſſel, and no other ſubſtance except the gaſes was introduced. Water then is compoſed of oxygen and hydrogen; and the combuſtion of hydrogen

38
Compoſition of water.

(M) Nitre is compoſed of potaſs and nitric acid; and nitric acid contains a great quantity of oxygen, which is eaſily ſeparated by heat. Diamond, when mixed with nitre, burns at a much lower heat than by any other proceſs.

(N) It was formerly called *inflammable air*, and by ſome chemiſts *phlogiſton*.

gen is nothing elſe but the act of its combination with oxygen (o).

It had been ſuppoſed, in conſequence of the experiments of Dr Prieſtley and ſeveral other philoſophers, that when hydrogen gas was allowed to remain in contact with water, it was gradually decompoſed, and converted into another gas; but Mr de Morveau,* Mr Haſſenfratz,† and Mr Libes,‡ have ſhewn, that it undergoes no change, provided ſufficient care be taken to exclude every other gas.

* Encycl. Method. Chim. i. 754
† Ann. de Chim. i. 192
‡ Jour. de Phyſ. xxxvi. 412.

Hydrogen gas diſſolves ſulphur, phoſphorus, and carbon. The compounds are called *ſulphurated*, *phoſphorated*, and *carbonated hydrogen gas*.

39
Compounds of hydrogen gas.

40
Sulphurated hydrogen gas.

1. Sulphurated hydrogen gas was firſt examined with attention by Scheele, who, together with Bergman, diſcovered many of its properties. Mr Kirwan likewiſe publiſhed a very valuable paper on the ſame ſubject. If equal parts of ſulphur and potaſs be melted together in a covered crucible, they combine together, and form a compound known by the name of *ſulphuret of potaſs*, but formerly called, from its red colour, *hepar ſulphuris*, or *liver of ſulphur*. When this ſubſtance is moiſtened with water, it gives out a quantity of ſulphurated hydrogen gas; hence this gas was at firſt called *hepatic gas*.

Mr Gengembre encloſed a bit of ſulphur in a glaſs veſſel filled with hydrogen gas, and melted the ſulphur by means of a burning glaſs. A quantity of it diſappeared, and the hydrogen aſſumed all the properties of *hepatic gas*. Hence it follows that this gas is merely ſulphur diſſolved in hydrogen gas.

The eaſieſt method of obtaining it is to pour an acid, the muriatic for inſtance, on a quantity of the ſulphuret reduced to powder. An effervescence takes place, the gas is extricated, and may be collected by means of a pneumatic apparatus. The theory of this emiſſion is obvious. The ſulphur is gradually converted into ſulphuric acid, by decompoſing the water, which is always united with acids, and ſeizing its oxygen: the hydrogen of the water is thus ſet at liberty; it aſſumes the gaſeous form, and at the ſame time diſſolves part of the remaining ſulphur, for which it has a conſiderable affinity.

The ſpecific gravity of ſulphurated hydrogen gas is 0,00135*; it is to common air as 1106 to 1000.

* Kirwan on Phlogiſton ſect. 1ſt.

It has a very fetid odour, preciſely ſimilar to that emitted by rotten eggs, which indeed is owing to the emiſſion of the very ſame gas.

It is not more reſpirable than hydrogen gas. When ſet on fire, in contact with oxygen gas, it burns with a light blue flame, without exploding, and at the ſame time a quantity of ſulphur is depoſited. The combuſtion of this gas, then, is merely the union of its hydrogen, and perhaps part of its ſulphur, with oxygen.

This gas turns ſyrup of violets to a green colour.* It does not ſeem capable of exiſting in atmoſpherical air without decompoſition; for the moment it comes into contact with oxygen gas, ſulphur is depoſited.†

* Fourcro Chemiſtry, art. Sulph
† Bergma

41
Phoſphor ted hydr gen gas.

2. Phoſphorated hydrogen gas was diſcovered by Mr Gengembre in 1783, and by Mr Kirwan ſome time after, before he became acquainted with the experiments of that gentleman. It may be procured by mixing phoſphorus with potaſs diſſolved in water, and applying a boiling heat to the ſolution. The phoſphorus is gradually converted into an acid by decompoſing the water, and uniting with its oxygen. The hydrogen aſſumes the form of a gas, and flies off after diſſolving a little of the phoſphorus. This gas may be collected by means of a pneumatic apparatus.

Phoſphorated hydrogen gas has a ſmell reſembling that of putrid fiſh. When mixed with oxygen gas or common air, it becomes luminous; and on the application of the ſmalleſt heat, it burns with aſtoniſhing rapidity.‡ The products are water and phoſphoric acid. The combuſtion of this gas therefore is nothing elſe than the union of its phoſphorus and hydrogen with oxygen, attended by an emiſſion of heat and light.

‡ Kirwan

Phoſphorated hydrogen gas may alſo be formed by introducing a bit of phoſphorus into a jar containing hydrogen gas; but care muſt be taken to make this gas as dry as poſſible; for its affinity with phoſphorus is weakened in proportion to its moiſture.||

|| Brugnat li, Nicholſon's Journal, i. 445

3. Carbonated hydrogen gas ariſes ſpontaneouſly in hot weather from marſhes, but always mixed with ſeveral other gaſes. Several ſpecies of it have been lately diſcovered by the aſſociated Dutch chemiſts Bondt, Dieman, Van Trooſtwyck, and Lauwerenberg.§ When 75 parts of ſulphuric acid and 25 of ſpirit of wine are mixed together, a gas is extricated which ſuffers no alteration from ſtanding over water. Its ſpecific gravity is 0,00111, or it is to common air as 909 to 1000. It has a fetid odour, and burns with a ſtrong compact flame. When paſſed through ſulphur it is converted into ſulphurated hydrogen gas, and at the ſame time a quantity of carbon is depoſited in the form of a fine powder; it muſt therefore be compoſed of carbon and hydrogen gas. When burnt, the product is carbonic acid

§ Ann. de Chim. xxi. 48.

42.
Carbonat hydrogen gas.

(o) The hiſtory of this great diſcovery, and the objections which have been made to it, we reſerve for the chapter which treats of *Water*, where they will be better underſtood than they could be at preſent. This ſubſtance was called *hydrogen* by the French chemiſts, becauſe it enters into the compoſition of water, from υδωρ *water*, and γινομαι *I am born*. Objections have been made to the propriety of the name, into which we ſhall not enter. It ought never to be forgotten, that Newton had long before, with a ſagacity almoſt greater than human, conjectured, from its great refracting power, that water *contained a combuſtible ſubſtance*. (4)

(4) That Newton *a-priori* from its refractive power ſhould have determined the *diamond* to be a *combuſtible* ſubſtance *may* reflect the higheſt credit on his genius. His determination of water containing an inflammable ſubſtance can however be conſidered but as a *lucky hit*. He aſcribed this inflammable principle to it on account of its great refractive power in proportion to its ſpecific gravity, the ſine of the angle of incidence being to the ſine of the angle of refraction in rock cryſtal 1.5620 to 1. and its gravity being 2.650 whereas in rain water whoſe ſpecific gravity is but 1. they bear the proportion of 1.3358 to 1. Had Newton applied this method of determining whether a ſubſtance contained an *inflammable principle* to other combinations of *oxygen* he would have fallen into groſs errors, in *ſulphuric acid*, for inſtance, whoſe ſpecific gravity is 2.125 the ſine of the angle of incidence is to that of refraction but as 1.4285 to 1. Hence he would have concluded that it contains *no inflammable* ſubſtance. T. P. S.

Ibid.

acid gas and water.* By making ether (p) paſs thro' a red hot glaſs tube, another carbonated hydrogen gas was formed, the ſpecific gravity of which was 0,00086. Spirit of wine, paſſed in the ſame manner, afforded a gas, the ſpecific gravity of which was 0,00053, and which burned with a paler flame than the other two. Theſe gaſes were found to contain from 80 to 74 parts of carbon, and from 20 to 26 of hydrogen. The firſt ſpecies was found to contain moſt carbon, and the laſt to contain leaſt †.

Ibid.

43
ffinities of
eſe gaſes.

The affinity of hydrogen gas for theſe three combuſtibles is as follows:

Sulphur,
Carbon,
Phoſphorus (q).

44
ttempt to
compoſe
rbon

Dr Auſtin found, that by repeatedly paſſing electric exploſions through a ſmall quantity of carbonated hydrogen gas, it was permanently dilated to more than twice its original bulk. He rightly concluded, that this remarkable expanſion could only be owing to the evolution of hydrogen gas. On burning air thus expanded, he found that it required a greater quantity of oxygen than the ſame quantity of gas not dilated by electricity: An addition therefore had been made to the combuſtible matter; for the quantity of oxygen neceſſary to complete the combuſtion of any body, is always proportional to the quantity of that body. He concluded from theſe experiments, that he had decompoſed the carbon which had been diſſolved in the hydrogen gas; and that carbon was compoſed of hydrogen and azot (r), ſome of which was always found in the veſſel after the dilated gas had been burnt by means of oxygen ‡. If this concluſion be fairly drawn, we muſt expunge *carbon* from the liſt of ſimple ſubſtances, and henceforth conſider it as a compound.

Phil.
anſ. lxxx.

45
amined,

There was one circumſtance which ought to have prevented Dr Auſtin from drawing this concluſion, at leaſt till warranted by more deciſive experiments. The quantity of combuſtible matter had been increaſed. Now, if the expanſion of the carbonated hydrogen gas was owing merely to the decompoſition of carbon, no ſuch increaſe ought to have taken place, but rather the contrary; for the carbon, which was itſelf a combuſtible ſubſtance, was reſolved into two ingredients, hydrogen and azot, only the firſt of which burnt on the addition of oxygen and the application of heat. Dr Auſtin's experiments have been lately repeated by Mr William Henry with a great deal of accuracy.* He found, that the dilatation which Dr Auſtin deſcribes actually took place, but that it could not be carried beyond a certain degree, a little more than twice the original bulk of the gas. Upon burning ſeparately by means of oxygen, two equal portions of carbonated hydrogen gas, one of which had been expanded by electricity to double its original bulk, the other not, he found that each of them produced preciſely the ſame quantity of *carbonic acid gas*. Both therefore contained the ſame quantity of carbon; conſequently no carbon had been decompounded by the electric ſhocks.

* Phil. Tran. 1797 part 2d.

46
And found
unſucceſsful.

Mr Henry then ſuſpected that the dilatation was owing to the water which every gas contains in a larger or ſmaller quantity. To aſcertain this, he endeavoured to deprive the carbonated hydrogen gas of as much water as poſſible, by making it paſs over very dry potaſs, which attracts water with avidity. Gas treated in this manner could only be expanded one-ſixth of its bulk; but on admitting a drop or two of water, the expanſion went on as uſual. The ſubſtance decompounded by the electricity, then, was not the carbon, but the water in the carbonated hydrogen gas. Nor is it difficult to ſee in what manner this decompoſition is effected. Carbon at a high temperature has a greater affinity for oxygen than hydrogen has; for if the ſteam of water be made to paſs over red hot charcoal, it is decompoſed, and carbonic acid and hydrogen gas are formed. The electric exploſion ſupplies the proper temperature; the carbon unites with the oxygen of the water, and forms carbonic acid; and the hydrogen, thus ſet at liberty, occaſions the dilation. Carbonic acid gas is abſorbed with avidity by water: and when water was admitted into 709 meaſures of gas thus dilated, 100 meaſures were abſorbed; a proof that carbonic acid gas was actually preſent. As to the azot which Dr Auſtin found in his dilated gas, it evidently proceeded from the admiſſion of ſome atmoſpheric air, about 73 parts of which in the 100 conſiſt of this gas: for Dr Auſtin's gas had ſtood long over water; and Drs Prieſtley and Higgins have ſhewn that air in ſuch a ſituation always becomes impregnated with azot. (5.)

(p) Ether is a very volatile and fragrant liquid, obtained by mixing ſpirit of wine and acids, and diſtilling. It ſhall be afterwards deſcribed.

(q) Sulphur decompoſes carbonated hydrogen gas; therefore its affinity is greater than that of carbon. The Dutch chemiſts melted phoſphorus in carbonated hydrogen gas, but no change was produced; therefore the affinity of phoſphorus is inferior to that of carbon.

(r) See next Section.—His theory was, that carbonated hydrogen gas was compoſed of hydrogen, and azot, and carbon of azot, and carbonated hydrogen gas, which comes nearly to the ſame thing with regard to the elements of carbon. It is ſingular enough, that though Dr Auſtin would not allow the preſence of carbon in carbonated hydrogen gas, he actually decompoſed it by melting ſulphur in it: the ſulphur combined with the hydrogen gas, and a quantity of carbon was precipitated. This experiment he relates without making any remarks upon it, and ſeems indeed not to have paid any attention to it.

(5) The decompoſition of the water held in ſolution by the *carbonated hydrogen gas* by means of the carbon uniting to the oxygen, and forming *carbonic acid gas* while the hydrogen is ſet at liberty, perfectly accounts for its increaſed bulk. But I think it by no means accounts for the increaſed *conſumption* of oxygen on firing it. It is true that there is an addition to the hydrogen in the reſervoir; but then we muſt recollect all the oxygen with which it was united, is now in union with the carbon; that therefore this carbon on the *combuſtion* taking place will combine with juſt ſo much the leſs of the oxygen added, and the *additional hydrogen* will require no more oxygen to reconvert it into water than it parted with to the carbon. I cannot ſee then with what this extra quantity is to unite. Is it not poſſible Dr Auſtin may have been deceived in an experiment which requires ſo much accuracy? T. P. S.

this theory he made the following addition: Phlogiſton is ſeparated during combuſtion by means of chemical affinity: *Air* (that is, *oxygen gas)* has a ſtrong affinity for phlogiſton: Its preſence is neceſſary during combuſtion, becauſe it combines with the phlogiſton as it ſeparates from the combuſtible; and it even contributes by its affinity to produce that ſeparation: The moment the air has combined with as much phlogiſton as it can receive, or, to uſe a chemical term, the moment it is *ſaturated* with phlogiſton, combuſtion neceſſarily ſtops, becauſe no more phlogiſton can leave the combuſtible (v): Air ſaturated with phlogiſton is azotic gas. This was a very ingenious theory, and when Dr Prieſtley publiſhed it, exceedingly plauſible. A great number of the moſt eminent chemiſts accordingly embraced it: But it was ſoon after diſcovered, that during combuſtion the quantity of air, inſtead of increaſing, as it ought to have done, had phlogiſton been added to it, actually diminiſhed both in volume and weight. There was no proof therefore, that during combuſtion, any ſubſtance whatever combined with air, but rather the contrary. It was diſcovered alſo, that a quantity of air combined with the burning ſubſtance during combuſtion, as we have ſeen was the caſe with ſulphur, phoſphorus, carbon, and hydrogen; and that this air had the properties of oxygen gas. Theſe diſcoveries entirely overthrew the evidence on which Dr Prieſtley's theory was founded: accordingly, as no attempt to decompound azot has ſucceeded, it has been given up by almoſt every chemiſt except Dr Prieſtley himſelf. Atmoſpheric air, as Scheele firſt proved, is compoſed of about 27 parts of oxygen, and 73 of azotic gas. During combuſtion, the oxygen is abſtracted and the azotic gas remains behind.

53
ſucceſs-

La Metherie made an attempt to prove that azot was compoſed of oxygen and carbon (w). He took a bit of burning charcoal, extinguiſhed it in mercury, and then plunged it while hot into oxygen gas. On being plunged into water, one-fourth of the gas was diſengaged, and part of it was found to conſiſt of azotic gas. From this he concluded that he had formed azotic gas by combining oxygen and carbon: But it was proved by Mr Lavoiſier, beyond the poſſibility of doubt, that oxygen and carbon form carbonic acid gas. They cannot then certainly form azot; for two contradictory facts cannot both be true. There muſt then have been ſomething overlooked in the experiment. Indeed the experiment itſelf does not warrant the concluſion which De La Metherie drew from it. He did not aſcertain whether the weight of the charcoal was diminiſhed; and beſides, there was azot mixed with the oxygen gas which he employed, as he himſelf has informed us: And how was it poſſible for him to admit the charcoal into water without, at the ſame time, admitting ſome atmoſpherical air?

We have now deſcribed all the combuſtibles which are at preſent reckoned ſimple, except the metals. We have found, that during combuſtion, all of them combine with oxygen; that no part of them is diſengaged, no part of them loſt: we have therefore concluded, that the combuſtion of theſe ſubſtances is nothing elſe but the act of their uniting with oxygen. We have ſeen, however, that none of them, except phoſphorus, was capable of uniting with oxygen at the common temperature of the atmoſphere; that, in order to produce the union, heat was neceſſary, and that the degree of this heat was different for each. Hydrogen required a red heat, and azot a ſtill greater (6). We have ſeen, too, that during theſe combinations a quantity of heat and light eſcaped. Now why is heat neceſſary for theſe combinations? and whence come the heat and the light which we perceive during the combuſtion of theſe bodies? Theſe queſtions are of the higheſt importance, and can only be anſwered by a particular inveſtigation of the nature and properties of heat and light. This inveſtigation we ſhall attempt as ſoon as we have deſcribed the *metals* and *earths*, which form the ſubject of the two following chapters.

Chap. III. *Of* Metals.

54
Properties of metals.

Metals may be conſidered as the great inſtruments of all our improvements: Without them, many of the arts and ſciences could hardly have exiſted. So ſenſible were the ancients of their great importance, that they raiſed thoſe perſons who firſt diſcovered the art of working them to the rank of deities. In chemiſtry, they have always filled a conſpicuous ſtation: at one period the whole ſcience was confined to them; and it may be ſaid to have owed its very exiſtence to a rage for making and tranſmuting metals.

55
Luſtre.

1. One of the moſt conſpicuous properties of the metals is a particular brilliancy which they poſſeſs, and which has been called the *metallic luſtre*. This proceeds from their reflecting much more light than any other body; a property which ſeems to depend partly on the cloſeneſs of their texture. This renders them peculiarly proper for mirrors, of which they always form the baſis.

56
Opacity.

2. They are abſolutely opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for inſtance, $\frac{1}{100000}$ of an inch thick, does not permit the ſmalleſt ray of light to paſs through it. Gold, however, may be rendered tranſparent; for gold leaf, $\frac{1}{280000}$ of an inch thick, tranſmits light of a lively green colour*. And it is not improbable that all the other metals, as Sir Iſaac Newton ſuppoſed, would become tranſparent, if they could be reduced to a ſufficient degree of thinneſs. It is to this opacity that a part of the excellence of the metals, as mirrors, is owing; their brilliancy alone would not qualify them for that purpoſe.

57
Fuſibility.

3. They may be melted by the application of heat, and even then ſtill retain their opacity. This property

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* *Nicholſon's Notes on Fourcroy.*

(v) This ingenious theory was firſt conceived by Dr. Rutherford, as appears from the following paſſage of his theſis. "Ex iiſdem etiam deducere licet quod aer ille malignus (azotic gas) componitur ex *aere atmoſpherico cum phlogiſto unito et quaſi ſaturato.* Atque idem confirmatur eo, quod aer qui metallorum calcinationi jam inſerviit, et phlogiſton ab iis abripuit ejuſdem plane ſit indolis." *De aere Mephitico*, p. 20.

(w) Or rather of *hydrogen*, for he conſidered carbon itſelf as a compound.

(6) If this be *true*, from whence comes the nitric acid in thoſe calcareous caves in which there is neither animal nor vegetable putrefaction, but in which nitre is formed?

enables us to caſt them in moulds, and then to give them any ſhape we pleaſe. In this manner many elegant iron utenſils are formed.

58 Gravity.

4. Their ſpecific gravity is greater than that of any other body hitherto diſcovered.

5. They are better conductors of electricity than any other body.

59 Malleability.

6. But one of their moſt important properties is *malleability*, by which is meant the capacity of being extended and flattened when ſtruck with a hammer. This property enables us to give the metallic body any form we think proper, and thus renders it eaſy for us to convert them into the various inſtruments for which we have occaſion. All metals do not poſſeſs this property; but it is remarkable that almoſt all thoſe which were known to the ancients have it. Heat increaſes this property conſiderably.

60 Ductility.

7. Another property which is alſo wanting in many of the metals, is *ductility;* by which we mean the capacity of being drawn out into wire, by being forced through holes of various diameters. This property has by ſome been called *tenacity;* and it doubtleſs depends upon the tenacity of the various metals.

61 Calcination

8. When expoſed to the action of heat and air, moſt of the metals loſe their luſtre, and are converted into earthy-like powders of different colours and properties, according to the metal, and the degree of heat employed. Several of the metals even take fire when expoſed to a ſtrong enough heat; and after combuſtion the reſiduum is found to be the very ſame earthy-like ſubſtance. If any of theſe *calces*, as they are called, be mixed with charcoal-powder, and expoſed to a ſtrong heat in a proper veſſel, it is changed again to the metal from which it was produced.

62 Stahl's theory of the compoſition of metals

From theſe phenomena Stahl concluded that metals were compoſed of *earth* and *phlogiſton*. He was of opinion that there was only one primitive earth, which not only formed the baſis of all thoſe ſubſtances known by the name of earths, but the baſis alſo of all the metals. He found, however, that it was impoſſible to combine any mere earth with phlogiſton; and concluded, therefore, with Beccher, that there was another principle beſides earth and phlogiſton which entered into the compoſition of the metals. To this principle Beccher gave the name of *mercurial earth*, becauſe according to him, it exiſted moſt abundantly in *mercury*. This principle was ſuppoſed to be very volatile, and therefore to fly off during calcination: and ſome chemiſts even affirmed that it might be obtained in the ſoot of thoſe chimneys under which metals have been calcined.

63 Defective.

A ſtriking defect was ſoon perceived in this theory. The original metal may be again produced by heating its calx along with ſome other ſubſtance which contains phlogiſton: now, if the mercurial earth flies off during combuſtion, it cannot be neceſſary for the formation of complete metals, for they may be produced without it: if, on the contrary, it adheres always to the calx, there is no proof of its exiſtence at all. Chemiſts, in conſequence of theſe obſervations, found themſelves obliged to diſcard the mercurial principle altogether, and to conclude that metals were compoſed of earth only, united to phlogiſton. But if this be really the caſe, how comes it that theſe two ſubſtances cannot be united by art?

64 Improved by Henkel

Henkel was the firſt who attempted to ſolve this difficulty. According to him, earth and phlogiſton are ſubſtances of ſo oppoſite a nature, that it is exceedingly difficult, or rather it has been hitherto impoſſible for us to commence their union; but after it has been once begun by nature, it is an eaſy matter to complete it. No calcination has hitherto deprived the metals of all their phlogiſton; ſome ſtill adheres to the calces. It is this remainder of phlogiſton which renders it ſo eaſy to reſtore them to their metallic ſtate. Were the calcination to be continued long enough to deprive them altogether of phlogiſton, they would be reduced to the ſtate of other earths; and then it would be equally difficult to convert them into metals, or, to uſe a chemical term, to *reduce* them. Accordingly we find, that the more completely a calx has been calcined, the more difficult is its reduction.

65 Farther im proved.

This explanation was favourably received. But after the characteriſtic properties of the various *earths* had been aſcertained, and the calces of metals were accurately examined, it was perceived that the calces differed in many particulars from all the *earths*, and from one another. To call them all the ſame ſubſtance, then, was to go much farther than either experiment or obſervation would warrant, or, rather, it was to declare open war againſt both experiment and obſervation. It was concluded, therefore, that each of the metals was compoſed of a peculiar *earthy ſubſtance* combined with phlogiſton. For this great improvement in accuracy, chemiſtry is chiefly indebted to Bergman.

66 Still imp fect.

But there were ſeveral phenomena of calcination which had all this time been unaccountably overlooked. The calces are all conſiderably heavier than the metals from which they are obtained. Boyle had obſerved this circumſtance, and had aſcribed it to a quantity of *fire* which, according to him, became fixed in the metal during the proceſs‡. But ſucceeding chemiſts paid little attention to it, or to the action of air, till Mr Lavoiſier publiſhed his celebrated experiments on calcination, in the memoirs of the Paris Academy for 1774. He put eight ounces of *tin* into a large glaſs retort, the point of which was drawn out into a very ſlender tube to admit of eaſy fuſion. This retort was heated ſlowly till the tin began to melt, and then ſealed hermetically. This heat was applied to expel ſome of the air from the retort; without which precaution it would have expanded and burſt the veſſel. The retort, which was capable of containing 250 cubic inches, was then weighed accurately, and placed again upon the fire.

67 Refuted Lavoiſie

The tin ſoon melted, and a pellicle formed on its top, which was gradually converted into a grey powder that ſunk by a little agitation, to the bottom of the liquid metal: in ſhort, the tin was partly converted into a *calx*. This proceſs went on for three hours; after which the calcination ſtopped, and no farther change could be produced on the metal. The retort was then taken from the fire, and found to be preciſely of the ſame weight as before the operation. It is evident, then, that no new ſubſtance had been introduced, and that therefore the increaſed weight of calces, cannot, as Boyle ſuppoſed, be owing to the fixation of fire (x).

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‡ *Fire and flame weig ed.*

(x) This experiment had been performed by Boyle with the ſame ſucceſs. He had drawn a wrong concluſion from not attending to the ſtate of the air of the veſſel. *Shaw's Boyle*, II. 394.

When the point of the retort was broken, the air ruſhed in with a hiſſing noiſe, and the weight of the retort was increaſed by ten grains. Ten grains of air, therefore, muſt have entered, and, conſequently, preciſely that quantity muſt have diſappeared during the calcination. The metal and its calx being weighed, were found juſt ten grains heavier than before: therefore, the air which diſappeared was abſorbed by the metal: and as that part of the tin which remained in a metallic ſtate was unchanged, it is evident that this air muſt have united with the calx. The increaſe of weight, then, which metals experience during calcination, is owing to their uniting with air (Y). But all the air in the veſſel was not abſorbed, and yet the calcination would not go on. It is not the whole, then, but ſome particular part of the air which unites with the calces of metals. By the ſubſequent diſcoveries of Prieſtley, Scheele, and Lavoiſier himſelf, it was aſcertained, that the reſiduum of the air, after calcination has been performed in it, is always pure azotic gas: It follows, therefore, that it is only the *oxygen* which combines with calces; and that a metallic calx is not a ſimple ſubſtance, but a compound. Mr Lavoiſier obſerved, that the weight of the calx was always equal to that of the metal employed, together with that of the oxygen abſorbed. It became a queſtion, then, Whether metals, during calcination, loſt any ſubſtance, and, conſequently, whether they contained any phlogiſton? Mr Lavoiſier accordingly propoſed this queſtion; and he anſwered it himſelf by a number of accurate experiments and ingenious obſervations. Metals cannot be calcined, excepting in contact with oxygen, and in proportion as they combine with it. Conſequently they not only abſorb oxygen during their calcination, but that abſorption is abſolutely neceſſary to their aſſuming the form of a calx. If the calx of mercury be heated in a retort, to which a pneumatic apparatus is attached, to the temperature of 1200°, it is converted into pure mercury; and, at the ſame time, a quantity of oxygen ſeparates from it in a gaſeous form. As this proceſs was performed in a cloſe veſſel, no new ſubſtance could enter: The calx of mercury, then, was reduced to a metallic ſtate without phlogiſton. The weights of the metal, and the oxygen gas, are together juſt equal to that of the calx; the calx of mercury, therefore, muſt be compoſed of mercury and oxygen; conſequently, there is no reaſon whatever to ſuppoſe that mercury contains phlogiſton. Its calcination is merely the act of uniting it with oxygen (Z). The calces of lead, ſilver, and gold, may be decompoſed exactly in the ſame manner; and Mr Van Marum, by means of his great electrical machine, decompoſed alſo thoſe of tin, zinc, and antimony, and reſolved them into their reſpective metals and oxygen‖. The ſame concluſions, therefore, muſt be drawn with reſpect to theſe metals. All the metallic calces may be decompoſed by preſenting to them ſubſtances which have a greater affinity for oxygen than they have. This is the reaſon that charcoal-powder is ſo efficacious in reducing them: and if they are mixed with it, and heated in a proper veſſel, furniſhed with a pneumatic apparatus, it will be eaſy to diſcover what paſſes. During the reduction, a great deal of carbonic acid gas comes over, which, together with the metal, is equal to the weight of the calx and the charcoal: it muſt therefore contain all the ingredients; and we know that carbonic acid gas is compoſed of carbon and oxygen. During the proceſs, then, the oxygen of the calx combined with the charcoal and the metal remained behind. It cannot be doubted, therefore, that all the metallic calces are compoſed of the entire metals combined with oxygen; and that calcination, like combuſtion, is merely the act of this combination. All metals, then, in the preſent ſtate of chemiſtry, muſt be conſidered as ſimple ſubſtances; for they have never yet been decompounded.

‖ *Jour. de Phyſ.* 1785.

68
Oxyd and oxydation what.

The words *calx* and *calcination* are evidently improper, as they convey falſe ideas; we ſhall therefore afterwards employ, in ſtead of them, the words *oxyd* and *oxydation*, which were invented by the French chemiſts. A metallic *oxyd* ſignifies a metal united with oxygen; and *oxydation* implies the act of that union.

Metals are capable of uniting with oxygen in different proportions, and, conſequently, of forming each of them different oxyds. Theſe are diſtinguiſhed from one another by their colour. One of the oxyds of iron, for inſtance, is of a green colour; it is therefore called the *green oxyd;* the other, which is brown, is called the *brown oxyd.*

69
Number of metals.

The metals at preſent amount to 21; only 11 of which were known before the year 1730. Their names are gold, ſilver, platinum, mercury, copper, iron, tin, lead, zinc, antimony, biſmuth, arſenic, cobalt, nickel, manganeſe,

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(Y) It is remarkable that John Rey, a phyſician of Perigord, had aſcribed it to this very cauſe as far back as the year 1630: But his writings had excited little attention, and had ſunk into oblivion, till after his opinion had been inconteſtibly proved by Lavoiſier. Mayow alſo, in the year 1674, aſcribed the increaſe of weight to the combination of metals with oxygen. *Quippe vix concipi poteſt* (ſays he), *unde augmentum illud antimonii (calcinati) niſi a particulis nitro-aereis igneiſque inter calcinandum* FIXIS *procedat.* Tract. p. 28. *Plane ut antimonii fixatio non tam a ſulphuris ejus externi aſſumptione, quam particulis nitro-aereis, quibus flamma nitri abundat,* EI INFIXIS *provenire videatur.* Ibid. p. 29.

(Z) This experiment was performed by Mr Bayen in 1774. This philoſopher perceived, earlier than Lavoiſier, that all metals did not contain phlogiſton. "Ces experiences (ſays he) vont nous detromper. Je ne tiendrai plus le language des diſciples de Stahl, qui feront forcés de reſtreindre la doctrine ſur le phlogiſtique, ou d'avouer que les precipités mercurials, dont je parle, ne ſont pas des chaux metalliques, ou enfin qu'il y a des chaux qui peuvent ſe reduire ſans le concours du phlogiſtique. Les experiences que j'ai faites me force de conclure que dans la chaux mercuriale dont je parle, le mercure doit ſon *etat calcaire, non à la perte du phlogiſtique* qu'il n'a pas eſſuyée, *mais a ſa combinaiſon intime avec le fluide elaſtique,* dont le poids ajouté a celui du mercure eſt la ſeconde cauſe de l'augmentation de peſanteur qu'on obſerve dans les precipités que j'ai ſoumis a l'examen." *Jour. de Phyſ.* 1774, pages 288, 295. It was in conſequence of hearing Bayen's paper read that Lavoiſier was induced to turn his attention to the ſubject.

atinum.

Peru, and in the mine of Santa Fe, near Carthagena. The workmen of theſe mines muſt no doubt have been early acquainted with it; but they ſeem to have paid very little attention to it. It was unknown in Europe till Mr Wood brought ſome of it from Jamaica in 1741. Soon after it was noticed by Don Antonio de Ulloa, a Spaniſh mathematician, who had accompanied the French academicians to Peru in their voyage to meaſure a degree of the meridian. In the year 1752, it was examined by Scheffer of Sweden, and diſcovered by him to be a new metal, approaching very much to the nature of gold, and therefore called by him *aurum album, white gold*. Soon after it was examined by Lewis, Margraf, Macquer and Beaumé, Morveau, Bergman, and many other illuſtrious chemiſts.

81
proper-
s.

Platinum, when pure, is of a white colour like ſilver, but not ſo bright (K). It has no taſte nor ſmell.

It is both ductile and malleable; but the preciſe degree has not yet been aſcertained. It has been drawn into a wire of $\frac{1}{1940}$ of an inch in diameter. This wire admitted of being flattened, and had more ſtrength than a wire of ſilver or gold of the ſame ſize‡.

‡ Vithering.

It is exceedingly difficult to fuſe it. Macquer and Beaumé ſucceeded by means of a powerful burning-glaſs. It melts more eaſily when mixed with other ſubſtances. Its fixity is ſtill greater than its infuſibility. If the ſtrongeſt fires cannot melt it, much leſs can they volatilize it.

Its hardneſs is 7,5‖. Its ſpecific gravity, after being hammered, is 23,000; ſo that it is by far the heavieſt body known.

‖ Kirwan's iner. ii. 3.

Some of the experiments which have been made on platinum ſeem to prove that it may be oxydated by the application of a violent heat. The oxyd of this metal may be eaſily formed by diſſolving platinum in nitro-muriatic acid, and precipitating it by means of an earth or potaſs. The various oxyds of platinum have never yet been examined with accuracy. The one at preſent beſt known poſſeſſes, as Mr Berthollet has proved, the properties of an acid.

82
hoſphuret
plati-
um.

The *ſulphuret of platinum* is unknown.

By mixing together an ounce of platinum, an ounce of phoſphoric glaſs, and a dram of powdered charcoal, and applying a heat of about 32° Wedgewood, Mr Pelletier formed a *phoſphuret of platinum* weighing more than an ounce. It was partly in the form of a button, and partly in cubic cryſtals. It was covered above by a blackiſh glaſs. It was of a ſilver white colour, very brittle, and hard enough to ſtrike fire with ſteel. When expoſed to a fire ſtrong enough to melt it, the phoſphorus was diſengaged, and burnt on the ſurface†.

† Ann. de him. i. 71.

He found alſo, that when phoſphorus was projected on red hot platinum, the metal inſtantly fuſed, and formed a phoſphuret. As heat expels the phoſphorus, Mr Pelletier has propoſed this as an eaſy method of purifying platinum*.

* Ibid. xiii. 05.

Platinum does not ſeem capable of combining with carbon.

Platinum
‖
Mercury.

It is not in the leaſt affected by the action of water or air.

83
Alloys of
platinum.

1. When gold and Platinum are expoſed to a ſtrong heat, they combine, and form an alloy of a much whiter colour, but nearly as ductile as gold. The proportions of the ingredients are not known. When $\frac{1}{47}$ only of the alloy is platinum, the gold is ſcarcely altered in colour.

2. Whether ſilver and platinum combine chemically has not yet been properly aſcertained. When fuſed together (for which a very ſtrong heat is neceſſary), they form a mixture not ſo ductile as ſilver, but harder and leſs white. The two metals are ſeparated by keeping them for ſome time in the ſtate of fuſion; the platinum ſinking to the bottom from its weight. This circumſtance would induce one to ſuppoſe that there is very little affinity between them.

Sect. IV. *Of Mercury.*

Mercury, called alſo *quickſilver*, was known to the ancients, and ſeems to have been employed by them in gilding.

84
Properties
of mercury.

It is of a white colour, exactly like that of poliſhed ſilver. It has no taſte, but acquires a ſlight odour when rubbed between the hands.

Its ſpecific gravity is 13,568†.

† Briſſon.

It differs from all other metals in always exiſting, at the common temperature of the atmoſphere, in a ſtate of fluidity. It freezes at 39°*; or, which is the ſame thing, it ceaſes to be a ſolid, and melts whenever it is placed in a temperature above 39°. It boils at the temperature of 600°.

* See *Macnab's Experiments Phil. Tranſ.*

From the experiments made on frozen mercury in Ruſſia, Hudſon's Bay, and Britain, we know that this metal, when ſolid, is malleable; but the extreme difficulty of examining it in that ſtate on account of the lowneſs of the temperature, has rendered it hitherto impoſſible to aſcertain the preciſe degree either of its malleability, ductility, or hardneſs.

85
It forms
three oxyds:

Mercury is capable of combining with oxygen, and of forming *oxyds*, differing from each other in the quantity of oxygen which they contain. The oxyds of mercury, at preſent known, are the *black*, the *yellow*, and the *red*.

86
The black
oxyd,

1. When mercury is agitated for ſome time in contact with oxygen gas, or atmoſpheric air, it is partly converted into a greyiſh-black powder, and at the ſame time part of the oxygen diſappears. This is the *black* oxyd of mercury. It is not known how much oxygen it contains, nor even whether the whole of the mercury which compoſes it be actually combined with oxygen.

87
Yellow
oxyd,

2. The beſt way of forming the yellow oxyd is to diſſolve mercury, either in boiling ſulphuric acid or in cold nitric acid. During its ſolution, it deprives theſe acids of juſt as much oxygen as is neceſſary to convert it

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bus non reſtitit. Et electro auctoritas, Homero teſte, qui Menelai regiam auro, electro, argento, ebore fulgere tradit. Minervæ templum habet Lindos inſulæ Rhodiorum in quo Helena ſacravit calicem ex electro.—Electri natura eſt ad lucernarum lumina clarius argento ſplendere. Quod eſt nativum, et venena deprehendit. Namque diſcurrunt in calicibus arcus cœleſtibus ſimiles cum igneo ſtridore, et gemina ratione prædicunt."—*Lib.* xxxiii. *cap.* iv.

(K) To this colour it owes its name. *Plata*, in Spaniſh, is *ſilver*; and *platina*, *little ſilver*, was the name firſt given to the metal. Bergman changed that name into *platinum*, that the Latin names of all the metals might have the ſame termination and gender. It was, however, firſt called *platinum* by Linnæus.

Mercury.

it into a yellow oxyd; and if potaſs or lime be afterwards added to the ſolution, it precipitates, and may be obtained pure by waſhing it with water. It is a bright yellow coloured powder, which acts very powerfully as an emetic. From the obſervations of Bergman, it appears that it is compoſed of about 96,8 parts of mercury, and 3,2 of oxygen*.

* Kirwan's Miner. ii. 489.

88 And red oxyd.

3. The *red oxyd* of mercury may be prepared, either by diſtilling nitric acid off the metal repeatedly, or by keeping mercury for a long time expoſed to a heat ſufficient to evaporate it while it is in contact with air. When formed by the firſt proceſs it was formerly called *red precipitate*; when by the laſt, *precipitate per ſe*. It is a beautiful red powder, or rather ſmall red cryſtals, which have ſome eſcharotic qualities. When prepared by the ſecond proceſs, the heat muſt not be much below 600°, nor much above 800°, otherwiſe no union would take place; and it muſt be continued for ſome weeks. From the experiments of Mr Kirwan, it appears to contain 92,6 parts of mercury, and 7,4 of oxygen*.

† Kirwan's Miner. ii. 489.

Theſe oxyds may be decompoſed by the application of a heat amounting to 1200°. The oxygen flies off in the form of gas, and running mercury remains behind.

89 Their affinities.

The affinities of the oxyds of mercury, according to Bergman, are as follows:

Sebacic acid,
Muriatic,
Oxalic,
Succinic,
Arſenic,
Phoſphoric,
Sulphuric,
Benzoic(L)?
Saccholactic,
Tartarous,
Citric,
Sulphurous,
Nitric,
Fluoric,
Zoonic(M)?
Acetous,
Boracic,
Pruſſic,
Carbonic.

90 Black ſulphuret of mercury.

When two parts of mercury and three parts of flowers of ſulphur are triturated for ſome time together, or when equal parts of mercury and melted ſulphur are mixed together, they combine, and form a black powder, formerly called *ethiops mineral*, and now *black ſulphuret of mercury*.

91. Red ſulphuret.

When 300 grains of mercury, and 68 of ſulphur, with a few drops of ſolution of potaſs to moiſten them, are triturated for ſome time in a porcelain cup, by means of a glaſs peſtle, black oxyd of mercury is produced. Add to this 160 grains of potaſs, diſſolved in as much water. Heat the veſſel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, ſo that the oxyd may be conſtantly covered to the depth of near an inch. The trituration muſt be continued abont two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which uſually happens when a large part of the fluid is evaporated. It then paſſes very rapidly to a red. No more water is to be added; but the trituration is to be continued without interruption. When the maſs has acquired the conſiſtence of a jelly, the red colour becomes more and more bright, with an incredible degree of quickneſs. The inſtant the colour has acquired its utmoſt beauty, the heat muſt be withdrawn, otherwiſe the red paſſes to a dirty brown. This red powder is the red ſulphuret of mercury, called formerly *cinnabar*, and, when reduced to a fine powder, *vermilion*(N). The proceſs above deſcribed, has been lately diſcovered by Mr Kirchoff, and is by far the ſimpleſt and cheapeſt mode of forming red ſulphuret with which we are acquainted*. Count De Mouſſin Pouſchin has diſcovered, that its paſſing to a brown colour may be prevented by taking it from the fire as ſoon as it has acquired a red colour, and placing it for two or three days in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. During this expoſure, the red colour gradually improves, and at laſt becomes excellent. He diſcovered alſo, that when this ſulphuret is expoſed to a ſtrong heat, it becomes inſtantly brown, and then paſſes into a dark violet; when taken from the fire, it paſſes inſtantly to a beautiful carmine red†.

* Nicholſ. Journ. ii.

† Ibid. p.

The difference between theſe two ſulphurets has never yet been aſcertained. One would be apt to ſuſpect at firſt that the black ſulphuret conſiſts of the real ſulphuret of mercury combined with ſulphur; the red, of the ſulphuret of mercury combined with mercury, and that the real ſulphuret of mercury was not yet accurately known. But it cannot be doubted that, during the formation of the *red ſulphuret*, according to Kirchoff's proceſs, there is an abſorption of oxygen. The phenomena above deſcribed point out *that* almoſt inconteſtibly; and we obſerved, on attempting to repeat the experiment, that the black ſulphuret, during its trituration, emitted ſulphurated hydrogen gas. Perhaps, then, the mercury may be oxydated. We ſuſpected at firſt that part of the ſulphur might be converted into an acid; but on attempting an alteration of the proceſs in conſequence of that ſuppoſition, we could not ſucceed.

The red ſulphuret of mercury is found naturally in ſeveral parts of the world. It uſed to be prepared by forming a black ſulphuret with three parts of ſulphur and one of mercury, and then ſetting fire to it. Part of the ſulphur is burnt, and there remains behind a violet coloured body, which is powdered and put into a glaſs veſſel, to the bottom of which a red heat is applied. A reddiſh

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(L) Benzoat of mercury is decompoſed by ſulphuric acid. *Trommſdorf Ann. de Chim.* xi. 316.

(M) Zoonic acid decompoſes the acetite of mercury. *Berthollet.*

(N) The word *vermilion*, is derived from the French word *vermeil*, which comes from *vermiculus* or *vermiculum*, names given in the middle ages to the *kermes*, or *cocus ilicis*, well known as a red dye. *Vermilion* originally ſignified the red dye of the kermes. See *Beckmann's Hiſt. of Diſcoveries*, II. 180.

A reddiſh brown ſubſtance ſublimes, which is red *ſulphuret of mercury* ; but its colour is not nearly equal to that which is prepared by Kerchoff's proceſs.

92 Phoſphuret of mercury.

Mr Pelletier, after ſeveral unſucceſsful attempts to form phoſphuret of mercury, at laſt ſucceeded by diſtilling a mixture of red oxyd of mercury and phoſphorus. Part of the phoſphorus combined with the oxygen of the oxyd, and was converted into an acid ; the reſt combined with the mercury.

Phoſphuret of mercury is of a black colour, of a pretty ſolid conſiſtence, and capable of being cut with a knife. When expoſed to the air, it exhaled vapours of phoſphorus‖.

‖ *Ann. de Chim.* xiii. 122.

Mercury does not ſeem capable of combining with carbon.

93 Its amalgams.

The combinations of mercury with the other metals are called *amalgams.*

1. The amalgam of gold forms very readily, becauſe there is a very ſtrong affinity between the two metals. If a bit of gold be dipped into mercury, its ſurface, by combining with mercury, becomes as white as ſilver. The eaſieſt way of forming this amalgam is to throw ſmall pieces of red hot gold into mercury. The proportions of the ingredients are not eaſily determined; becauſe the amalgam has an affinity both for the gold and the mercury ; in conſequence of which they appear to combine in any proportion. Moſt probably it is compoſed of two parts of gold and one of mercury. The combination is formed moſt readily in theſe proportions ; and if too much mercury be added, it may be ſeparated by filtration. The amalgam is of a white colour, and of the conſiſtence of butter†. This amalgam cryſtallizes in quadrangular priſms ; which cryſtals, according to the Dijon academicians, are compoſed of ſix parts of mercury and one of gold. It is much uſed in gilding.

† *Keir's Notes on Macquer's Dict.* art. *Amalgam.*

2. The amalgam of ſilver is made in the ſame manner. It forms dendritical cryſtals, which, according to the Dijon academicians, contain eight parts of mercury and one of ſilver. Gellert was the firſt who remarked that its ſpecific gravity was greater than that of mercury, though that of ſilver be leſs.

3. Dr Lewis attempted to form an amalgam of platinum, but hardly ſucceeded, after a labour which laſted for ſeveral weeks. Mr Morveau ſucceeded by means of heat†. But a much more expeditious method has been lately diſcovered by Count Mouſſin Pouſchin. He took a dram of the orange-coloured ſalt, compoſed of *oxyd of platinum and ammonia* (o), and triturated it with an equal weight of mercury in a mortar of chalcedony. In a few minutes the ſalt became brown, and afterwards acquired a greeniſh ſhade. The matter was reduced to a very fine powder. Another dram of mercury was added, and the trituration continued : The matter became grey. A third dram of mercury began to form an amalgam ; and ſix drams made the amalgam perfect. The whole operation ſcarce laſted 20 minutes. Mercury was added till it amounted to nine times the weight of the ſalt, and yet the amalgam continued very tenacious. It was eaſily ſpread out under the peſtle ; it received the impreſſion of the moſt delicate ſeals, and had a very cloſe and brilliant grain. This amalgam is decompoſed, and the mercury paſſes to the ſtate of black oxyd by the ſimple contact of ſeveral of the metals and a great number of animal matters. This effect even takes place on rubbing it between the fingers*.

† *Ann. de Chim.* xxiv. 205.

* *Ibid.*

94 Affinities.

The affinities of mercury, as aſcertained by the experiments of Morveau (p), are as follows :

Gold,
Silver,
Tin,
Lead,
Biſmuth,
Zinc,
Copper,
Antimony,
Arſenic (q),
Iron.

Sect. V. *Of Copper.*

Except gold and ſilver, copper ſeems to have been more early known than any other metal. In the firſt ages of the world, before the method of working iron was diſcovered, copper was a principal ingredient in all domeſtic utenſils and inſtruments of war. Even during the Trojan war, as we learn from Homer, the combatants had no other armour but what was made of bronze, which is a mixture of *copper and tin.* The word *copper* is derived from the iſland of Cyprus, where it was firſt diſcovered, or at leaſt wrought to any extent, by the Greeks.

95 Properties of copper.

Copper is of a pale red colour with a ſhade of yellow. Its taſte is ſtyptic and nauſeous ; and when rubbed it emits a diſagreeable ſmell. It poſſeſſes a conſiderable degree of malleability, though leſs than ſilver. Its tenacity is ſuch, that a wire of $\frac{1}{10}$ of an inch in diameter can ſuſtain a weight of 299¼ pounds without breaking†.

† *Macquer's Dict.*

Its hardneſs is 8 ‡. Its ſpecific gravity, when not hammered, is 7,788 ; when wire-drawn, 8,878‖. The ſpecific gravity of Japan copper is 9,000* ; that of Swediſh copper, 9,3243†.

‡ *Kirwan's Miner.* ii. 127.
‖ *Briſſon.*
* *Keir's Notes on Macquer's Dict.*
† *Bergman,* ii. 263.

It melts at 27° Wedgewood ; according to the calculation of the Dijon academicians, at 1449° Fahrenheit. When allowed to cool ſlowly, it aſſumes a cryſtalline form. The Abbé Mongez, to whom we owe many valuable experiments on the cryſtallization of metals, informs us, that theſe cryſtals are quadrangular pyramids, frequently inſerted into one another.

96 Brown oxyd of copper.

When copper is heated red hot in contact with air, it is ſoon covered with a brown earthy cruſt, which may be eaſily ſeparated by hammering or by plunging the metal into water. If the heat be continued, another ſcale of the ſame kind ſoon forms ; and by continuing the proceſs the whole metal may be converted into an earthy-like cruſt, which is merely a combination of copper and oxygen, and is therefore called *brown oxyd of copper.* It is compoſed of about 84 parts of copper and 16 of oxygen‡.

‡ *Kirwan's Miner.* ii. 487.

97 Blue and green oxyds.

When copper is diſſolved in ſulphuric acid, and precipitated by means of lime, it falls in the form of a blue-coloured powder, which is the *blue oxyd of copper.* If

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(o) Ammonia is an alkali hereafter to be deſcribed. It is often called, in Engliſh, *hartſhorn.*

(p) We ſhall have occaſion to conſider theſe celebrated experiments afterwards.

(q) Theſe two are added from Bergman. Bergman places *lead* before tin, and zinc before biſmuth.

this oxyd of copper be dried in the open air, it aſſumes a green colour, and is then called the *green oxyd of copper*. This laſt oxyd may alſo be produced by diſtilling a ſufficient quantity of nitric acid off copper. Little ſatisfactory is yet known with reſpect to theſe oxyds; it has not even been aſcertained whether the blue and green be really two different oxyds, or whether the difference in colour be owing to ſome other cauſe. It is probable, however, that the *green* oxyd contains more oxygen than the blue; becauſe the blue oxyd aſſumes a green colour when expoſed for ſome time to the open air, during which it may be ſuppoſed to abſorb oxygen. An experiment of Fourcroy proves inconteſtibly, that the *brown* oxyd contains leſs oxygen than the green. He converted the green oxyd into the brown by applying heat; and during the diſtillation obtained oxygen gas||.

98
Their affinities.

The affinities of the oxyds of copper, according to Bergman, are as follows:

Pyromucous acid*,
Oxalic,
Tartarous,
Muriatic,
Sulphuric,
Saccholactic,
Nitric,
Sebacic,
Arſenic,
Phoſphoric,
Succinic,
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Fixed alkalies,
Ammonia,
Fixed oils.

When copper is long expoſed to the air, its ſurface becomes covered over with a green cruſt, which is *green oxyd of copper*. This oxydation never penetrates beyond the ſurface.

Copper is not attacked by water at the boiling temperature; but if cold water be allowed to remain long on its ſurface, the metal becomes partly oxydated.

99
Sulphuret of copper.

Sulphur mixes readily with copper. The combination may be formed by mixing the ingredients together and applying a pretty ſtrong heat. *Sulphuret of copper* is brittle, ſofter than copper, of a black colour externally, and within of a leaden grey. It is compoſed, according to Kirwan's experiments, of 81 parts of copper and 19 of ſulphur*.

100
Phoſphuret of copper.

Mr Pelletier formed *phoſphuret of copper* by melting together one ounce of copper, one ounce of phoſphoric glaſs, and one dram of charcoal. It was of a white colour. On expoſure to the air, it loſt its luſtre and became blackiſh‡. Margraf was the firſt perſon that formed this phoſphuret. His method was to diſtil phoſphorus and brown oxyd of copper together. It is formed moſt eaſily by projecting phoſphorus into red hot copper. According to Pelletier, it contains 20 parts of phoſphorus and 80 of copper*. This phoſphuret is harder than iron: It is not ductile, and yet cannot eaſily be pulveriſed. Its ſpecific gravity is 7,1220. It cryſtallizes in tetrahedral priſms‡.

101
Alloys of copper.

1. Copper combines readily with gold when the two metals are melted together. The compound is of a reddiſh colour, more fuſible than gold, but leſs ductile. The proportions of the ingredients which form this alloy are not known; nor would it be eaſy to aſcertain them, as the two metals are almoſt equally fuſible. The current gold of this country is compoſed of 11 parts of gold and one part of copper.

2. The alloy of copper and ſilver is made as eaſily as that of gold, and the properties are equally unknown. It is harder and more ſonorous than ſilver. The current ſilver coin of Britain is compoſed of 15 parts of ſilver and one of copper.

3. Platinum combines readily with copper. The alloy is much more fuſible than platinum; it is ductile, hard, takes a fine poliſh, and is not liable to tarniſh. This alloy has been employed with advantage for compoſing the mirrors of reflecting teleſcopes.

4. The amalgam of copper cannot be formed by ſimply mixing that metal with mercury, nor even by the application of heat; becauſe the heat neceſſary to melt copper ſublimes mercury. Dr Lewis has given us ſeveral proceſſes for forming this amalgam. One of the ſimpleſt is to triturate mercury with a quantity of common ſalt and verdigriſe; a ſubſtance compoſed of oxyd of copper and vinegar. The theory of this proceſs is not very obvious.

102
Its affinities.

The affinities of copper are, according to Bergman, as follows:

Gold,
Silver,
Arſenic,
Iron,
Mangeneſe,
Zinc,
Antimony,
Platinum,
Tin,
Lead,
Nickel,
Biſmuth,
Cobalt,
Mercury,
Sulphuret of alkali,
Sulphur,
Phoſphorus.

Sect. VI. *Of Iron.*

103
Diſcovery of iron.

Iron, the moſt abundant and moſt uſeful of all the metals, was neither known ſo early, nor wrought ſo eaſily, as gold, ſilver, and copper. For its diſcovery we muſt have recourſe to the nations of the eaſt, among whom, indeed, almoſt all the arts and ſciences firſt ſprung up. The writings of Moſes (who was born about 1635 years before Chriſt) furniſh us with the ampleſt proof at how early a period it was known in Egypt and Phœnicia. He mentions furnaces for working iron‡, ores from which it was extracted*; and tells us, that ſwords||, knives¶, axes†, and tools for cutting ſtones§, were then made of that metal. How many ages before the birth of Moſes iron muſt have been diſcovered in theſe countries, we may perhaps conceive, if we reflect, that the knowledge of iron was brought

|| Fourcroy, iii. 101.

* Schrickel.

* Kirwan's Miner. ii. 508.

‡ Ann. de Chim. i. 74.

* Ibid. xiii. 3.

‡ Sage, Journ. de Phyſ. xxxviii. 468

‡ Deut. i 20.

* Ibid. vii 9.

|| Numb. xxxv. 16.

¶ Levit. i 17.

† Deut. xviii. 5.

§ Ibid. xxv 5.

brought over from Phrygia to Greece by the Dactyli*, who ſettled in Crete during the reign of Minos I. about 1431 years before Chriſt; yet during the Trojan war, which happened 200 years after that period, iron was in ſuch high eſtimation, that Achilles propoſed a ball of it as one of his prizes during the games which he celebrated in honour of Patroclus (R). At that period none of their weapons were formed of iron. Now if the Greeks in 200 years had made ſo little progreſs in an art which they learned from others, how long muſt it have taken the Egyptians, Phrygians, Chalybes, or whatever nation firſt diſcovered the art of working iron, to have made that progreſs in it which we find they had done in the days of Moſes?

104 Its properties.

Iron, when freſh broken, is of a bluiſh grey colour. It has a ſtyptic taſte, and emits a ſmell when rubbed.

It is malleable and ductile in every temperature; and its malleability is increaſed in proportion as the temperature augments. Its tenacity is ſuch, that an iron wire $\frac{1}{10}$ of an inch in diameter ſuſtains a weight of 450 pounds without breaking.*

Its hardneſs is ſuch, that it may be eaſily reduced to powder by the application of a file. Its ſpecific gravity is 7,788. It is infuſible in the ſtrongeſt heats hitherto produced.

It is attracted by the magnet or loadſtone, and is itſelf capable of becoming magnetic; but it retains this property only for a very ſhort time.

It is not hardened by being plunged into liquids while hot, nor ſoftened by being cooled ſlowly.

Iron combines with oxygen very readily. When kindled in oxygen gas, it burns with great rapidity and ſplendor, and is in this manner converted into an oxyd. It is converted into an oxyd alſo when ſurrounded by moiſt air, or when plunged in water; becauſe it has a ſtronger affinity for oxygen than hydrogen has, and is therefore capable of decompoſing water.

105 Forms two oxyds.

Mr Prouſt has lately proved, that there are only two oxyds of iron, the *green*, and the *brown* or *red*, and that all the other ſuppoſed oxyds are merely mixtures of theſe two in various proportions†.

The *green oxyd* may be obtained by diſſolving iron in ſulphuric acid, and then precipitating it by potaſs. It is a light, green-coloured, earthy-like ſubſtance, compoſed, as Mr Lavoiſier has ſhewn, of 27 parts of oxygen, and 73 of iron‡. When this oxyd is expoſed to the air, it quickly abſorbs more oxygen, and is converted into a brown powder, which is the *brown oxyd*. Mr Prouſt has proved that it contains 52 parts of iron and 48 of oxygen. This oxyd is well known under the name of *ruſt of iron*, which is generally, however, or perhaps always, combined with carbonic acid gas.

106 Their affinities.

The affinities of theſe oxyds, according to Bergman, are as follows:

Gallic acid,
Oxalic acid,
Tartarous,
Camphoric,*
Sulphuric,
Saccholactic,
Muriatic,
Pyromucous‡,
Nitric,
Sebacic,
Phoſphoric,
Arſenic,
Fluoric,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic.

107 Sulphuret,

Iron unites readily with ſulphur. Sulphuret of iron, formerly called *pyrites*, is found ready formed in many parts of the world. It is not eaſy to determine the proportions of its ingredients, becauſe it is capable of combining both with iron and ſulphur, and conſequently, if there happens to be any exceſs of either during its formation, it takes it up. Perhaps the proportions are not far from equal parts of ſulphur and of iron. It is of a pale yellow or browniſh colour, and is capable of aſſuming a cryſtalline form. Its ſpecific gravity is about 4,000. When placed upon the fire, it precipitates; and at a red heat loſes its yellow colour, and becomes of an iron grey, excepting its ſurface, which is of a bright red. It melts at 102° Wedgewood in a covered crucible into a bluiſh ſlag, ſomewhat porous internally.‡ When expoſed to air and moiſture, the ſulphur, as happens in all ſulphurets, gradually abſorbs oxygen, and is converted into an acid.

If iron filings and ſulphur be mixed together, and formed into a paſte with water, the ſulphur decompoſes the water, and abſorbs oxygen ſo rapidly that the mixture takes fire, even though it be buried under ground. This phenomenon was firſt diſcovered by Homberg; and it is conſidered as affording an explanation of the origin of volcanoes. The native ſulphuret of iron has been obſerved more than once to take fire on being ſuddenly moiſtened with water.

208 Phoſphuret,

Iron combines readily with phoſphorus, and forms *phoſphuret of iron*; to which Bergman, who firſt diſcovered it, gave the name of *ſiderum*.

There is a particular kind of iron, known by the name of *cold ſhort iron*, becauſe it is brittle when cold, though it be malleable when hot. Bergman was employed

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(R) Αυταρ Πηλειδης θηκεν σολον αυτοχοωνον,
Ὁν ϖριν μεν ριπτασκε μεγα σθενος Ηετιωνος·
Αλλ' ητοι τὸν επεφνε ϖοδαρκης διος Αχιλλευς,
Τον δ' αγετ' εν νηεσσι συν αλλοισι κτεατεσσι.
Στη δ' ορθος, ϗ μυθον εν Αργειοισιν εειπεν·
Ορνυσθ', οἱ ϗ τȣτȣ αεθλȣ ϖειρησεσθε·
Ει οἱ ϗ μαλα πολλον αποπροθι ϖιονες αγροι,
Ἑξει μιν ϗ ϖεντε ϖεριπλομενȣς ενιαυτȣς
Χρεωμενος· ȣ μεν γαρ οἱ ατεμβομενος γε σιδηρȣ
Ποιμην ȣδ' αροτηρ, εισ' ες ϖολιν, αλλα ϖαρεξει. Iliad, xxiii. l. 826.

* *Heſiod*, as quoted by *Pliny*, lib. vii. c. 57.

* *Macquer's Dict.*

† *Ann. de Chim.* xxiii. 35. and *Nicholſon's Journal*, i. 153.

‡ *Mem. Acad. Par.* 1782.

* *La Grange.*

‡ *Schrickel.*

‡ *Kirwan's Miner.* ii. 76.

ployed at Upſal in examining the cauſe of this property, while Meyer was occupied at Stetin with the ſame inveſtigation; and both of them diſcovered, nearly at the ſame time, that, by means of ſulphuric acid, a white powder could be ſeparated from this kind of iron, which by the uſual proceſs they converted into a metal of a dark ſteel grey, exceedingly brittle, and not very ſoluble in acids. Its ſpecific gravity was 6,700; it was not ſo fuſible as copper; and when combined with iron rendered it *cold ſhort*. Both of them concluded that this ſubſtance was a new metal; and Bergman gave it the name of *ſiderum*. But Klaproth ſoon after recollecting that the ſalt compoſed of phoſphoric acid and iron bore a great reſemblance to the white powder obtained from cold ſhort iron, ſuſpected the preſence of phoſphoric acid in this new metal. To decide the point, he combined phoſphoric acid and iron, and obtained, by heating it in a crucible along with charcoal powder (s), a ſubſtance exactly reſembling the new metal. Meyer, when Klaproth communicated to him this diſcovery, informed him that he had already ſatisfied himſelf, by a more accurate examination, that ſiderum contained phoſphoric acid. Soon after this, Scheele actually decompoſed the white powder obtained from cold ſhort iron, and thereby demonſtrated, that it was compoſed of phoſphoric acid and iron. The ſiderum of Bergman, however, is compoſed of phoſphorus and iron, the phoſphoric acid being deprived of its oxygen during the *reduction*; or it is phoſphuret of iron. It may be formed by fuſing in a crucible an ounce of phoſphoric glaſs, an ounce of iron, and half a dram of charcoal powder. It is very brittle, and appears white when broken. When expoſed to a ſtrong heat, it melts, and the phoſphorus is diſſipated.* It may be formed alſo by melting together equal parts of phoſphoric glaſs and iron-filings. Part of the iron combines with the oxygen of the phoſphoric glaſs, and is vitrified; the reſt forms the phoſphuret, which ſinks to the bottom of the crucible. It may be formed alſo by dropping ſmall bits of phoſphorus into iron-filings heated red hot‡. The proportions of the ingredients of this phoſphuret have not yet been determined.

109 And carburet of iron.

Iron likewiſe combines with carbon, and forms a *carburet*. Carburet of iron has been long known and uſed in the arts under the names of *plumbago* and *black lead*. It is of a dark iron grey or blue colour, and has ſomething of a metallic luſtre. It has a greaſy feel, and blackens the fingers, or any other ſubſtance to which it is applied. It is found in many parts of the world, eſpecially in England, where it is manufactured into pencils. It is not affected by the moſt violent heat as long as air is excluded, nor is it in the leaſt altered by ſimple expoſure to the air, or to water. Its nature was firſt inveſtigated by Scheele; who proved, by a very ingenious analyſis, that it could be converted almoſt wholly into carbonic acid gas, and that the ſmall reſiduum was iron. It follows from this analyſis, that it is compoſed of carbon and iron; for the carbon during its combuſtion had been converted into carbonic acid gas. By the ſubſequent experiments of Pelletier and other French chemiſts, it has been ſhewn to conſiſt nearly of nine parts of carbon to one of iron.

110 Varieties of iron.

There are a great many varieties of iron, which artiſts diſtinguiſh by particular names; but all of them may be reduced under one or other of the three following ſtates: *Wrought iron* (or ſimply *iron*), *ſteel*, and *caſt* or *raw iron*.

111 Wrought iron.

WROUGHT IRON is the ſubſtance which we have been hitherto deſcribing. As it has never yet been decompounded, we conſider it when pure as a ſimple body; but it has ſeldom or never been found without ſome ſmall mixture of foreign ſubſtances. Theſe ſubſtances are either ſome of the other metals, or oxygen, carbon, or phoſphorus.

112 Steel.

STEEL is diſtinguiſhed from iron by the following properties.

It is ſo hard as to be unmalleable while cold, or at leaſt it acquires this property by being immerſed while ignited into a cold liquid: for this immerſion, though it has no effect upon *iron*, adds greatly to the hardneſs of *ſteel*.

It is brittle, reſiſts the file, cuts glaſs, affords ſparks with flint, and retains the magnetic virtue for any length of time.

It loſes this hardneſs by being ignited and cooled very ſlowly.

It melts at above 130° Wedgewood. It is malleable when red hot, but ſcarcely ſo when raiſed to a white heat.

It may be hammered out into much thinner plates than iron. It is more ſonorous; and its ſpecific gravity, when hammered, is greater than that of iron.

By being repeatedly ignited in an open veſſel, and hammered, it becomes *wrought iron*†.

113 Caſt iron.

CAST IRON is diſtinguiſhed by the following properties:

It is ſcarcely malleable at any temperature. It is generally ſo hard as to reſiſt the file. It can neither be hardened nor ſoftened as ſteel can by ignition and cooling. It is exceedingly brittle. It melts at 130° Wedgewood. It is more ſonorous than ſteel.*

Caſt iron is converted into wrought iron by expoſing it for a conſiderable time in a furnace to a heat ſufficiently ſtrong to melt it. During the proceſs it is conſtantly ſtirred by a workman, that every part of it may be equally expoſed to the air. In about an hour the hotteſt part of the maſs begins to heave and ſwell, and to emit a lambent blue flame. This continues nearly an hour; and by that time the converſion is completed. The heaving is evidently produced by the emiſſion of an elaſtic fluid‡.

Wrought iron may be converted into ſteel by being kept for ſome hours in a ſtrong red heat, ſurrounded with charcoal powder in a covered crucible. By this proceſs, which is called *cementation*, the iron gains ſome weight.

114 Cauſe of theſe varieties.

Theſe different kinds of iron have been long known, and the converting of them into each other has been practiſed in very remote ages. Many attempts have been made to explain the manner in which this converſion is accompliſhed. According to Pliny, ſteel owes its peculiar properties chiefly to the water into which it is plunged in order to be cooled§. Beccher ſuppoſed that fire was the only agent; that it entered into the iron, and converted it into ſteel. Reaumur was the firſt who attended accurately to the proceſs; and his numerous experiments have certainly contributed to elucidate the ſubject. He ſuppoſed that iron was converted into to ſteel by combining with ſaline and oily or ſulphureous particles, and that theſe were introduced by the fire. But it was the analyſis of Bergman, publiſhed in 1781, that firſt paved the way to the explanation of the nature of theſe different ſpecies of iron.

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* *Pelletier, Ann. de Chim.* i. 104.

‡ *Id. Ann. de Chim.* xiii. 113.

† *Dr Pea ſon on Wootz, Phi Tranſ.*

* *Ibid.*

‡ *Beddoes, Phil. Tra* 1791.

§ *Pliny,* l. xxxiv. 1

(s) This proceſs in chemiſtry is called *reduction*.

By diſſolving in diluted ſulphuric acid 100 parts of caſt iron, he obtained 40 ounce meaſures of hydrogen; from 100 parts of ſteel he obtained 48 ounce meaſures; and from 100 parts of wrought iron, 50 ounce meaſures. Now as the hydrogen is produced by the property which iron has of decompoſing water and uniting with its oxygen, it is evident that the greater the quantity of hydrogen obtained, with the more oxygen does the iron combine. But the quantities of iron were equal; they ought therefore to have combined with eqnal quantities of oxygen. But it is evident, from the quantities of hydrogen obtained, that the caſt iron received leſs oxygen than either of the other two: caſt iron therefore muſt contain already ſome oxygen, ſince it requires leſs than the other two ſpecies in order to be ſaturated. Here then is one difference between caſt iron and the other two kinds; it contains oxygen. Steel, on the contrary, does not appear to contain any oxygen. The difference between the quantity of hydrogen produced during its ſolution and that of wrought iron, which contains no oxygen, is exceedingly ſmall, and it has been found to diminiſh in proportion to the purity of the ſteel.

From 100 parts of caſt iron Bergman obtained 2,2 of plumbago, or $\frac{1}{45}$; from 100 parts of ſteel, 0,5, or $\frac{1}{200}$; and from 100 parts of wrought iron, 0,12, or $\frac{1}{900}$. Now plumbago is compoſed of $\frac{9}{10}$ths of carbon; caſt iron therefore contains a conſiderable quantity of carbon, ſteel a ſmaller quantity, and wrought iron a very minute portion, which diminiſhes according to its purity, and would vaniſh altogether if iron could be obtained perfectly pure. Mr Grignon, in his notes on this analyſis, endeavoured to prove, that plumbago was not eſſentially a part of caſt iron and ſteel, but that it was merely accidentally preſent. But Bergman, after conſidering his objections, wrote to Morveau on the 18th November 1783. "I will acknowledge my miſtake whenever Mr Grignon ſends me a ſingle bit of caſt iron or ſteel which does not contain plumbago; and I beg of you, my dear friend, to endeavour to diſcover ſome ſuch, and to ſend them to me; for if I am wrong, I wiſh to be undeceived as ſoon as poſſible."* This was almoſt the laſt action of the illuſtrious Bergman. He died a few months after at the age of 49, leaving behind him a moſt brilliant reputation, which no man ever more deſervedly acquired. His induſtry, his indefatigable, his aſtoniſhing induſtry, would alone have contributed much to eſtabliſh his name; his extenſive knowledge would alone have attracted the attention of philoſophers; his ingenuity, penetration, and accurate judgment, would alone have ſecured the applauſe; and his candour and love of truth procured him the confidence and the eſteem of the world—But all theſe qualities were united in Bergman, and conſpired to form one of the greateſt men and nobleſt characters that ever adorned human nature.

*Morveau, ycl. Me- t. Chi- i. 448.

The experiments of Bergman were fully confirmed by thoſe of Morveau, Vandermonde, Monge, and Berthollet, who have likewiſe thrown a great deal of additional light on the ſubject. From all theſe experiments the following deductions may be made.

Wrought iron is a ſimple ſubſtance, and if perfectly pure would contain nothing but *iron*.

Steel is iron combined with carbon. The proportion of this laſt ingredient has not yet been aſcertained; Dr Pearſon fixes it at $\frac{1}{300}$th part at a medium. Steel, in conſequence of its compoſition, has been called by ſome chemiſts *carburet of iron;* but before aſſigning it that name, which has been alſo given to plumbago, it ought to be determined what are the proportions of carbon and iron which ſaturate each other. Is it the proportion in which theſe two ſubſtances exiſt in ſteel, or that which forms plumbago? In the firſt caſe, plumbago is carburet of iron combined with carbon; in the ſecond, ſteel is carburet combined with iron. Or is it ſome intermediate proportion? Till theſe points be determined, perhaps it would be better to continue the old names than to riſk the impoſing of falſe ones.

Caſt iron is iron contaminated with various foreign ſubſtances, the proportions of which vary according to circumſtances. Theſe ſubſtances are chiefly oxyd of iron and carbon, and ſometimes ſilica (T).

Bergman found a quantity of manganeſe in the iron and ſteel which he examined; but it appears from the experiments of Vauquelin, that his method of determining the preſence of that metal was not accurate.

Mr Vauquelin* has lately analyſed four kinds of ſteel with great care, and contrived his proceſſes with much ingenuity. The reſult of his analyſis is as follows:

* *Jour. de Mines.* See *Nicholſon's Journal*, i. 200.

115
Vauquelin's analyſis of ſteel.

Firſt ſteel, compoſed of	Carbon, -	0,00789
	Silica, -	0,00315
	Phoſphorus,	0,00345
	Iron, -	0,98551
		1

Second ſteel, compoſed of	Carbon, -	0,00683
	Silica, -	0,00273
	Phoſphorus	0,00827
	Iron, -	0,98217
		1

Third ſteel, compoſed of	Carbon, -	0,00789
	Silica, -	0,00315
	Phoſphorus,	0,00791
	Iron -	0,98105
		1

Fourth ſteel, compoſed of	Carbon, -	0,00631
	Silica, -	0,00252
	Phoſphorus,	0,01520
	Iron, -	0,97597
		1

It cannot be concluded from theſe experiments, that all ſteel contains phoſphorus and ſilica; far leſs that theſe ſubſtances enter neceſſarily into the compoſition of ſteel. This *may* be the caſe, and former analyſes may not have been nice enough to detect it; but before it can be admitted, it muſt be ſhewn that theſe ſubſtances are always preſent in ſteel, and that it loſes its eſſential properties when deprived of them.

(T) An earth which ſhall be deſcribed in the next chapter.

Iron || Tin.

Iron combines with moſt metals.

116
Alloys of iron.

1. The alloy of gold and iron is very hard, and might, according to Dr Lewis who examined it, be employed with advantage in forming cutting inſtruments.

2. That iron combines with ſilver is certain, but hardly any thing is known about the nature of the compound.

3. Platinum is uſually found alloyed with iron. Dr Lewis did not ſucceed in his attempts to unite theſe metals by fuſion, but he melted together caſt iron and platinum. The alloy was exceſſively hard, and poſſeſſed ductility.

4. There is very little affinity between iron and mercury; they cannot therefore be amalgamated by ſimple mixture, even with the aſſiſtance of heat. Vogel affirms that he has produced an amalgam of iron by the following proceſs; Pound one part of iron filings and two parts of alum in a mortar to a fine powder; then pour in two or three parts of mercury, and triturate till the ſubſtances be thoroughly mixed. Pour on a little water, and continue the trituration for about an hour. If then no particles of iron can be diſtinguiſhed, pour on a little more water to waſh out the alum, and then dry the amalgam. If particles of iron be perceptible, the trituration muſt be continued till they diſappear.*

5. Iron may be united to copper by fuſion, but not without conſiderable difficulty. The alloy has been applied to no uſe.

117
Its affinities.

The affinities of iron, according to Bergman, are as follows:

Nickel,
Cobalt,
Mangaueſe,
Arſenic,
Copper,
Gold,
Silver,
Tin,
Antimony,
Platinum,
Biſmuth,
Lead,
Mercury,
Sulphuret of alkali,
Carbon?
Phoſphorus?
Sulphur?

Sect. VII. *Of Tin.*

The Phenicians were the firſt of thoſe nations which make a figure in ancient hiſtory that were acquainted with *tin*. They procured it from Spain* and from Britain, with which nations they carried on a very lucrative commerce. At how early a period they imported this metal we may eaſily conceive, if we recollect that it was in common uſe in the time of Moſes †.

118
Properties of tin:

Tin is of a greyiſh white colour; it has a ſtrong diſagreeable taſte, and emits a peculiar ſmell when rubbed.

It is very malleable; tin leaf, or *tinfoil* as it is called, is about $\frac{1}{1000}$th part of an inch thick, and it might be beat out into leaves as thin again if ſuch were wanted for the purpoſes of art. Its ductility, however, is exceedingly imperfect; for a tin wire $\frac{1}{10}$th of an inch in diameter, is capable of ſupporting only 49 pounds without breaking ‡. It is very flexible, and produces a crackling noiſe when bended.

Its hardneſs is 6+. Its ſpecific gravity is 7,291; after hammering, 7,299 ||.

It melts at the temperature 410°, according to Dr Lewis; according to the Dijon academicians, at 419°. When heated red hot in cloſe veſſels it ſublimes. It cryſtallizes in the form of a rhomboidal priſm.*

119
Oxyds

Tin unites very readily with oxygen. When heated in contact with air, its ſurface ſoon becomes covered with a grey pellicle; when this is taken off, another appears ſoon after; and in this manner the whole metal may be converted into a dirty grey powder, which is the *grey oxyd of tin*. It is compoſed, according to Fourcroy, of 90 parts of tin and 10 of oxygen.

When tin is heated red hot in contact with air, it takes fire †, and burns with a very lively white flame, and is gradually ſublimed. If the ſublimate be examined, it is found to conſiſt of a white powder; it is the *white oxyd of tin*. The white oxyd is perhaps never obtained quite pure by this proceſs; it ſeems always to contain a mixture of *grey oxyd*: but it may be obtained pure by pouring nitric acid upon tin, and then drying it. That metal having a much ſtronger attraction for oxygen than azot has, decompoſes the acid with the greateſt rapidity, and aſſumes the appearance of a white powder, which is the *white oxyd*. This oxyd poſſeſſes many of the properties of an acid, and is therefore often called *ſtannic acid*. It ſeems to conſiſt of about 77 parts of tin and 23 of oxygen ‡.

The affinities of the grey oxyd of tin, according to Bergman, are as follows:

Pyromucous acid,*
Sebacic acid,
Tartaric,
Muriatic,
Sulphuric,
Oxalic,
Arſenic,
Phoſphoric,
Nitric,
Succinic,
Fluoric,
Saccholactic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic.

120
Sulphur

Tin combines readily with ſulphur. This ſulphuret may be formed by fuſing the two ingredients together. It is brittle, heavier than tin, and not ſo fuſible. It is of a bluiſh colour and lamellated ſtructure, and is capable of cryſtallizing. According to Bergman, it is compoſed of 80 parts of tin and 20 of ſulphur; according to Pelletier, of 85 parts of tin and 15 of ſulphur.*

Sulphur likewiſe combines with the white oxyd of tin, by mixing them together, and applying a gentle heat.† This compound has been called *aurum muſivum*. It is a maſs conſiſting of beautiful gold coloured flakes, and is uſed as a paint. It is compoſed of about 40 parts of ſulphur and 60 of white oxyd of tin ‡. The proceſs for making this ſubſtance was formerly very complicated. Pelletier firſt demonſtrated its real compoſition, and

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* *Ann. de Chim.* vi. 39.

* *Pliny*, l. 4. c. 34. *and* l. 34. c. 47.

† *Numbers* xxxi. 22.

‡ *Macqu Dictionai*

† *Kirwa Miner.* i 195.

|| *Briſſon*

* *Pajot. Jour. de Phyſ.* xxxviii.

† *Geoffro*

‡ *Kirwe Miner.* 488.

* *Scbric*

* *Ann. Chim.* xi 287.

† *Pelleti Ibid.* p. 2

‡ *Ibid.* 2

Arſenic,
Tartarous,
Phoſphoric,
Muriatic,
Benzoic (u) ?
Sulphurous,
Suberic ? } *(v)*
Zoonic ? }
Nitric,
Pyromucous (v) ?
Fluoric,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Fixed alkali.

When lead is expoſed to heat in contact with air, its ſurface is ſoon covered with a grey pellicle; when this is taken off, another ſoon forms: and in this manner, the whole lead may ſoon be converted into a dirty grey powder, which ſeems to be the white oxyd mixed with a little lead. When this powder is heated red hot, it aſſumes a deep yellow colour. This is the *yellow oxyd* of lead, formerly called *maſſicot*. If the heat be continued, the colour is gradually changed to a beautiful red. This is the *red oxyd of lead*, formerly called *minium*. It is compoſed, as Lavoiſier has ſhewn, of 88 parts of lead and 12 of oxygen*.

The manner in which theſe changes are brought about is evident; the metal gradually abſorbs oxygen from the atmoſphere. This has been actually proved by experiment. Theſe oxyds (if they really differ in the proportion of oxygen) reſemble acids in ſeveral of their properties. They are very eaſily converted into glaſs by fuſion. Scheele has ſhewn that there is alſo a *brown oxyd of lead*, which contains more oxygen than any of the others.

126 Sulphuret, Sulphur unites eaſily to lead by fuſion. The ſulphuret of lead is brittle, of a deep grey colour, and much leſs fuſible than lead. Theſe two ſubſtances are often found naturally combined; the compound is then called *galena*. Sulphuret of lead is compoſed, according to the experiments of Wenzel, of 868 parts of lead, and 132 of ſulphur†.

127 Phoſphuret, Phoſphuret of lead may be formed by mixing together equal parts of filings of lead and phoſphoric glaſs, and fuſing them in a crucible. It may be cut with a knife, but ſeparates into plates when hammered. It is of a ſilver white colour with a ſhade of blue, but it ſoon tarniſhes when expoſed to the air. This phoſphuret may alſo be formed by dropping phoſphorus into melted lead. It is compoſed of about 12 parts of phoſphorus and 88 of lead‡.

128 Alloys, Lead combines with moſt of the other metals.

1. Little is known concerning the alloy of lead and gold. It is ſaid to be brittle.

2. The alloy of ſilver and lead is very fuſible, and neither elaſtic nor ſonorous.

3. Platinum and lead unite in a ſtrong heat: the alloy is brittle, of a purpliſh colour, and ſoon changes on expoſure to the air§.

4. Mercury, when poured upon melted lead, diſſolves it readily. The amalgam is white and brilliant, and aſſumes a ſolid form. It is capable of cryſtallizing. The cryſtals are compoſed of one part of lead and one and a half of mercury.||

5. Copper and lead combine eaſily by fuſion; but the alloy has not been applied to any uſe.

6. Iron does not unite with lead.

7. Lead and tin may be combined by fuſion. The alloy in the proportion of two parts of lead, and one of tin, is more ſoluble than either of the metals ſeparately. It is accordingly uſed by plumbers as a ſolder.

129 Affiniti Lead, when taken internally, acts as a poiſon. Its affinities, according to Bergman, are as follows:

Gold,
Silver,
Copper,
Mercury,
Biſmuth,
Tin,
Antimony,
Platinum,
Arſenic,
Zinc,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phoſphorus?

13c Names marks given t the met by the cients. The ancients gave to the ſeven metals laſt deſcribed (omitting *platinum*, which they did not know) the names of the planets, and denoted each of them by particular marks, which repreſented both the planet and the metal.

Gold was the Sun, and repreſented by ☉.
Silver the Moon, ☾.
Mercury Mercury, ☿.
Copper Venus, ♀.
Iron Mars, ♂.
Tin Jupiter, ♃.
Lead Saturn, ♄.

It ſeems moſt probable that theſe names were firſt given to the planets; and that the ſeven metals, the only ones then known, were ſuppoſed to have ſome relation to the planets or to the gods that inhabited them, as the number of both happened to be the ſame. It appears from a paſſage in Origen, that theſe names firſt aroſe among the Perſians (w). Why each particular metal

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* *Mem. Par.* 1781.

† *Kirwan's Miner.* ii. 492.

‡ *Pelletier, Ann. de Chim.* xiii. 114.

§ *Fourc*

|| *Dijon cademici*

(u) Benzoat of lead is decompoſed by muriatic acid. *Trommſdorf, Ann. de Chim.* xi. 317.

(v) Suberic acid decompoſes nitrat of lead. See *Jameſon's Mineralogy*, p. 166. Zoonic acid produces the ſame effect, as Berthollet has obſerved.

(v) Schrikel places it after the three mineral acids.

(w) *Contra Celſum*, lib. vi. 22.—"Celſus de quibuſdam Perſarum myſteriis ſermonem facit. Harum rerum, inquit, aliquod reperitur in Perſarum doctrina Mithraciſque eorum myſteriis veſtigium. In illis enim duæ cœleſtes converſiones, alia ſtellarum fixarum, errantium alia, et animæ per eas tranſitus quodam ſymbolo repræſentantur, quod

metal was denominated by a particular planet it is not eaſy to ſee. Many conjectures have been made, but ſcarcely any of them are ſatisfactory.

131 rigin of ıeſe marks cording the a- ologers;

As to the characters by which theſe metals were expreſſed, aſtrologers ſeem to have conſidered them as the attributes of the deities of the ſame name. The circle in the earlieſt periods among the Egyptians was the ſymbol of divinity and perfection; and ſeems with great propriety to have been choſen by them as the character of the ſun, eſpecially as, when ſurrounded by ſmall ſtrokes projecting from its circumference, it may form ſome repreſentation of the emiſſion of rays. The ſemicircle is, in like manner, the image of the moon; the only one of the heavenly bodies that appears under that form to the naked eye. The character ♄ is ſuppoſed to repreſent the ſcythe of Saturn; ♃ the thunderbolts of Jupiter; ♂ the lance of Mars, together with his ſhield; ♀ the looking-glaſs of Venus; and ☿ the caduceus or wand of Mercury.

132 cording the al- miſts.

The alchemiſts, however, give a very different account of theſe ſymbols. Gold was the moſt perfect metal, and was therefore denoted by a circle. Silver approached neareſt it; but as it was inferior, it was denoted only by a ſemicircle. In the character ☿ the adepts diſcovered gold with a ſilver colour. The croſs at the bottom expreſſed the preſence of a myſterious ſomething, without which mercury would be ſilver or gold. This ſomething is combined alſo with copper; the poſſible change of which into gold is expreſſed by the character ♀. The character ♂ declares the like honourable affinity alſo; though the ſemicircle is applied in a more concealed manner: for, according to the propereſt mode of writing, the point is wanting at the top, or the upright line ought only to touch the horizontal, and not to interſect it. Philoſophical gold is concealed in ſteel; and on this account it produces ſuch valuable medicines. Of tin, one half is ſilver, and the other conſiſts of the unknown ſomething; for this reaſon the croſs with the half moon appears in ♃. In lead this ſomething is predominant, and a ſimilitude is obſerved in it to ſilver. Hence in its character ♄ the croſs ſtands at the top, and the ſilver character is only ſuſpended on the right hand behind it.

133 ir real in.

The fact, however, according to Profeſſor Beckmann, from whom moſt of the above remarks have been taken, ſeems to be, that theſe characters are mere abbreviations of the old names of the planets. "The character of Mars (he obſerves*), according to the oldeſt mode of repreſenting it, is evidently an abbreviation of the word Θουρος, under which the Greek mathematicians underſtood that deity; or, in other words, the firſt letter Θ, with the laſt letter ς placed above it. The character of Jupiter was originally the initial letter of Ζευς; and in the oldeſt manuſcripts of the mathematical and aſtrological works of Julius Firmicus, the capital Z only is uſed, to which the laſt letter ς was afterwards added at the bottom, to render the abbreviation more diſtinct. The ſuppoſed looking-glaſs of Venus is nothing elſe than the initial letter diſtorted a little of the word Φωσφορος, which was the name of that goddeſs. The imaginary ſcythe of Saturn has been gradually formed from the two firſt letters of his name Κρονος, which tranſcribers, for the ſake of diſpatch, made always more convenient for uſe, but at the ſame time leſs perceptible. To diſcover in the pretended caduceus of Mercury the initial letter of his Greek name Στιλϐων, one needs only look at the abbreviations in the oldeſt manuſcripts, where they will find that the Σ was once written as C; they will remark alſo that tranſcribers, to diſtinguiſh this abbreviation from the reſt ſtill more, placed the C thus ◡, and added under it the next letter τ. If thoſe to whom this deduction appears improbable will only take the trouble to look at other Greek abbreviations, they will find many that differ ſtill farther from the original letters they expreſs than the preſent character ☿ from the C and τ united. It is poſſible alſo that later tranſcribers, to whom the origin of this abbreviation was not known, may have endeavoured to give it a greater reſemblance to the caduceus of Mercury. In ſhort, it cannot be denied that many other aſtronomical characters are real ſymbols, or a kind of proper hieroglyphics, that repreſent certain attributes or circumſtances, like the characters of Aries, Leo, and others quoted by Saumiſe."

* iſtory of I ntions, Engliſh tr ſlation, iii 67.

Sect. IX. *Of Zinc.*

134 Diſcovery of zinc.

The ancients were acquainted with a mineral to which they gave the name of *Cadmea*, from Cadmus, who firſt taught the Greeks to uſe it. They knew that when melted with copper it formed braſs; and that when burnt, a white ſpongy kind of aſhes was volatiliſed, which they uſed in medicine*. This mineral contained a good deal of zinc; and yet there is no proof remaining that the ancients were acquainted with that metal (x). It is firſt mentioned in the writings of Albertus Magnus, who died in 1280; but whether he had ſeen it is not ſo clear, as he gives it the name of *marcaſite of gold*, which implies,

* *Pliny*, l. 34. c. 2. and 10.

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quod hujuſmodi eſt. Scala altas portas habens, in ſumma autem octava porta. Prima portarum plumbea, altera ſtannea, tertia ex ære, quarta ferrea, quinta ex ære mixto, ſexta argentea, ſeptima ex auro. κλιμαξ ὑψιπυλος, επι δ' αιτη πυλη ογδοη. Ἡ πρωτη των πυλων μολιϐδου, ἡ δευτερα κασσιτερου, ἡ τριτη χαλκου, ἡ τεταρτη σιδηρου, ἡ πεμπτη καρασου νομισματος, ἡ ἑκτη αργυρου, χρυσου δ' ἡ ἑϐδομη. Primum aſſignant Saturno tarditatem illius ſideris plumbo indicantes: alteram Veneri, quam referunt, ut ipſi quidem putant ſtanni ſplendor et mollities; tertiam Jovi, aheneam illam quidem et ſolidam: quartam Mercurio, quia Mercurius et ferrum, uterque operum omnium tolerantes, ad mercaturam utiles, laborum patientiſſimi. Marti quintam, inæqualem illam et variam propter mixturam. Sextam, quæ argentea eſt, lunæ; ſeptimam auream ſoli tribuunt, quia ſolis et lunæ colores hæc duo metalla referunt."

Borrichius ſuſpects, with a good deal of probability, that the names of the gods in this paſſage have been tranſpoſed by tranſcribers, either through ignorance or deſign. He arranges them as follows: "Secundam portam faciunt Jovis, comparantes ei ſtanni ſplendorem et mollitiem; tertiam Veneris æratam et ſolidam; quartam Martis, eſt enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter miſturam inæqualem ac variam, et quia negotiator eſt; ſextam Lunæ argenteam; ſeptimam Solis auream." *Ol. Borrichius de ortu et progreſſu chemiæ.* Hafniæ, 1668, 4to. p. 29.

(x) Grignon indeed ſays, that ſomething like it was diſcovered in the ruins of an ancient Roman city in Champagne; but the ſubſtance which he took for it was not examined with any accuracy. It is impoſſible therefore to draw any inference whatever from his aſſertion. *Bulletin des fouilles d'une ville Romaine.* p. 11.

implies, one would think, that it had a yellow colour (y). The word *zinc* occurs firſt in the writings of Paracelſus, who died in 1541. He informs us very gravely, that it is a metal, and not a metal, and that it conſiſts chiefly of the aſhes of copper[†]. This metal has alſo been called *ſpelter*.

Zinc has never been found in Europe in a ſtate of purity, and it was long before a method was diſcovered of extracting it from its ore (z). Henkel pointed out one in 1721, and Von Swab obtained it by diſtillation in 1742, and Margraf publiſhed a proceſs in the Berlin Memoirs in 1746[‡].

135
Properties of zinc.

It is of a bluiſh white colour, ſomewhat lighter than lead. It has neither taſte nor ſmell.

It has ſome degree of malleability; for by compreſſion it may be reduced into thin plates[§]; but it cannot be drawn out into wire. It is more brittle when hot than when cold.

Its hardneſs is 6[*]. Its ſpecific gravity, when compreſſed, is 7,1908[†]; in its uſual ſtate, 6,862[‡]. It melts at about 699° Fahrenheit[§].

When allowed to cool ſlowly, it cryſtallizes in ſmall bundles of quadrangular priſms, diſpoſed in all directions. If they are expoſed to the air while hot, they aſſume a blue changeable colour[*].

136
Its oxyds,

When zinc is kept melted in contact with air, it becomes covered with a grey pellicle, which gradually aſſumes a yellowiſh tint. By removing this pellicle from time to time, the whole of the metal may be reduced into a grey powder. This is the *grey oxyd of zinc*. This oxyd is probably compoſed of about 85 parts of zinc and 15 of oxygen[†]. When zinc is violently heated, it burns with a bright white flame, and at the ſame time a quantity of very light white flakes are ſublimed. Theſe flakes are the *white oxyd of zinc*, which contains a good deal more oxygen than the grey oxyd (a).

Zinc may alſo be oxydated by ſolution in acids, particularly the nitric acid. Whether the oxyd obtained by precipitating zinc from its ſolution in that acid, or by diſtilling that acid off zinc, be really different from the white oxyd, has not yet been properly aſcertained; but one would be apt to ſuſpect, from the experiments mentioned by Mr Kirwan, that it contained a good deal more oxygen[‖].

The affinities of the oxyds, or rather of the white oxyd of zinc, are, according to Bergman, as follows:

Oxalic acid,
Sulphuric,
Pyromucous[*],
Muriatic,
Saccholactic,
Nitric,
Sebacic,
Tartaric,
Phoſphoric,
Citric,
Succinic,
Fluoric,
Arſenic,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic,
Ammonia.

137
Sulphur

There is an affinity between ſulphur and zinc, as is evident from theſe two ſubſtances being often found united; but it is very difficult to form the ſulphuret of zinc artificially, on account of the rapid oxydation and conſequent volatilization of the zinc. Morveau, however, ſucceeded in forming it.

138
Phoſphu
rets,

Zinc may be combined with phoſphorus, by dropping ſmall bits of phoſphorus into it while in a ſtate of fuſion. Pelletier, to whom we are indebted for the experiment, added alſo a little reſin, to prevent the oxydation of the zinc. Phoſphuret of zinc is of a white colour, a metallic ſplendor, but reſembles lead more than zinc. It is ſomewhat malleable. When hammered or filed, it emits the odour of phoſphorus. When expoſed to a ſtrong heat, it burns like zinc[*].

Phoſphorus

[†] See *Vol.* 6. *of his Works in* 4to.

[‡] *Bergman*, ii. 309.

[§] *Sage*.

[*] *Kirwan's Miner.* ii. 232.

[†] *Briſſon.*

[‡] *Kirwan*, *ibid.*

[§] *Bergman.*

[*] *Mongez.*

[†] *Morveau*, *Kirwan's Miner.* ii. 489.

[‖] *Miner* ii. 499.

[*] *Schric*

[*] *Ann.* *Chim.* xi 129.

(y) The paſſages in which he mentions it are as follows:—*De Mineral.* lib. ii. cap. 11. "Marchaſita, ſive marchaſida ut quidam dicunt, eſt lapis in ſubſtantia, et habet multas ſpecies, quare colorem accipit cujuſlibet metalli, et ſic dicitur marchaſita argentea et aurea, et ſic dicitur aliis. Metallum tamen quod colorat eum non diſtillat ab ipſo, ſed evaporat in ignem, et ſic relinquitur cinis inutilis, et hic lapis notus eſt apud alchimicos, et in multis locis veniuntur.

Lib. iii. chap. 10. "Æs autem invenitur in venis lapidis, et quod eſt apud locum qui dicitur Goſelaria eſt puriſſimum et optimum, et toti ſubſtantiæ lapidis incorporatum, ita quod totus lapis eſt ſicut marchaſita aurea, et profundatum eſt melius ex eo quod purius.

Lib. v. cap. 5. "Dicimus igitur quod marchaſita duplicem habet in ſui creatione ſubſtantiam, argenti vivi ſcilicet mortificati, et ad fixionem approximantis, et ſulphuris adurentis. Ipſam habere ſulphureitatem comperimus manifeſta experientia. Nam cum ſublimatur, ex illa emanat ſubſtantia ſulphurea manifeſta comburens. Et ſine ſublimatione ſimiliter perpenditur illius ſulphureitas.

"Nam ſi ponatur ad ignitionem, non ſuſcipit illam priuſquam inflammatione ſulphuris inflammetur, et ardeat. Ipſam vero argenti vivi ſubſtantiam manifeſtatur habere ſenſibiliter. Nam albedinem præſtat Veneri meri argenti, quemadmodum et ipſum argentum vivum, et colorem in ipſius ſublimatione cæleſtium præſtare, et luciditatem manifeſtam metallicam habere videmus, quæ certum reddunt artificem Alchimiæ, illam has ſubſtantias continere in radice ſua."

(z) The real diſcoverer of this method appears to have been Dr Iſaac Lawſon. See *Pott*, III. diſſ. 7. and *Watſon's Chemical Eſſays*.

(a) Pott obſerved, that it was $\frac{1}{10}$th heavier than the zinc from which it was obtained; and Mr Boyle had long before aſcertained the ſame fact.—*Shaw's Boyle*, II. 391, 394.

This oxyd of zinc was well known to the ancients. Dioſcorides deſcribes the method of preparing it. The ancients called it *pompholyx*, the early chemiſts gave it the name of *lana philoſophica*. Dioſcorides compares it to wool, εριων τολυπαις αφομοιουνται, v. 85. p. 352.

deſcribes the proceſs. To him indeed we are indebted for our acquaintance with many of the properties of this metal.

Antimony is of a white colour, with a ſhade of grey. It has a ſenſible taſte, but no ſmell ‖.

143 Properties of antimony. It is neither malleable nor ductile, but exceedingly brittle. Its ſpecific gravity, according to Briſſon, is 6,702; according to Bergman, 6,860. Its hardneſs is 6,5 §. It melts at 809° Fahrenheit ¶. If after this the heat be increaſed, the metal evaporates. On cooling it aſſumes the form of oblong cryſtals, perpendicular to the internal ſurface of the veſſel in which it cools. It is to this cryſtallization that the laminated ſtructure which antimony always aſſumes is owing.

144 Its oxyds. Neither air nor water have much effect on this metal. When antimony is beat to powder, and expoſed for ſome time to a gentle heat, it abſorbs oxygen, and is converted into a grey powder. This is the *grey oxyd of antimony*. When this metal is kept for ſome time melted in contact with air, it ſublimes in the form of a white powder, formerly called *ſnow* or *white flowers of antimony*. This is the *white oxyd of antimony*. This oxyd may be procured alſo by pouring nitric acid on antimony, and then evaporating to dryneſs. Antimony attracts the oxygen from the acid, and thus paſſes very rapidly into the ſtate of an oxyd. This oxyd ſeems to conſiſt of about 77 parts of antimony and 23 of oxygen.* The nature of theſe oxyds has never yet been accurately inquired into. It is not even known at preſent whether the white oxyd obtained by heat and that obtained by nitric acid contain the ſame quantity of oxygen. The experiments mentioned by Mr Kirwan make the contrary probable †; and yet theſe oxyds have too many qualities in common to render theſe experiments concluſive. The white oxyd of antimony is ſoluble in water ‡; and when fuſed, is converted into a tranſparent glaſs. The white oxyd obtained by nitric acid ſeems to poſſeſs many of the properties of an acid.

The affinities of the grey oxyd of antimony are, according to Bergman, as follows:

Sebacic acid,
Muriatic,
Benzoic (D)?
Oxalic,
Sulphuric,
Pyromucous §,
Nitric,
Tartarous,
Saccholactic,
Phoſphoric,
Citric,
Succinic,
Fluoric,
Arſenic,
Formic,
Lactic,
Acetous,
Boracic,
Pruſſic,
Carbonic.

145 Sulphurets. Sulphur combines readily with antimony. This compound is often found native: it was formerly called antimony, and the pure metal was then called *regulus of antimony*. Sulphuret of antimony is eaſily melted by a moderate heat: if the heat be continued, the ſulphur ſublimes, and at the ſame time the antimony abſorbs oxygen, and is converted into a grey oxyd. This ſulphuret is compoſed of 74 parts of antimony and 26 of ſulphur.*

The grey oxyd of antimony is alſo capable of combining with about $\frac{4}{100}$ of ſulphur. This compound, by fuſion, may be converted into glaſs. It was formerly uſed in medicine under the name of *glaſs of antimony*.

146 Phoſphuret. When equal parts of antimony and phoſphoric glaſs are mixed together with a little charcoal powder, and melted in a crucible, phoſphuret of antimony is produced. It is of a white colour, brittle, appears laminated when broken, and at the fracture there appear a number of ſmall cubic facettes. When melted it emits a green flame, and then ſublimes in the form of a white powder. Phoſphuret of antimony may likewiſe be prepared by fuſing equal parts of antimony and phoſphoric glaſs, or by dropping phoſphorus into melted antimony †.

147 Alloys. Antimony is capable of combining with moſt of the metals.

1. Gold may be alloyed with antimony by fuſing them together. The antimony is afterwards ſeparable by an intenſe heat. This alloy is little known, and has never been applied to any uſe.

2. The alloy of ſilver and antimony is brittle, and its ſpecific gravity, as Gellert has obſerved, is greater than intermediate between the ſpecific gravities of the two metals which enter into it.

3. Platinum eaſily combines with antimony. The alloy is brittle, and much lighter than platinum.* The antimony cannot afterwards be completely ſeparated by heat.

4. Mercury does not eaſily combine with antimony. Mr Gellert ſucceeded in amalgamating this metal by putting it into hot mercury, and covering the whole with water.

5. Copper combines readily with antimony by fuſion. The alloy is of a beautiful violet colour, and its ſpecific gravity is greater than intermediate †.

6. Iron combines with antimony, and forms a brittle hard alloy, the ſpecific gravity of which is leſs than intermediate. The magnetic quality of iron is much more diminiſhed by being alloyed with antimony than with any other metal ‡.

7. The alloy of tin and antimony is white and brittle; its ſpecific gravity is leſs than intermediate §.

8. When equal quantities of lead and antimony are fuſed, the alloy is porous and brittle: three parts of lead and one of antimony form a compact alloy, malleable, and much harder than lead: 12 parts of lead and one of antimony form an alloy very malleable, and a good deal harder than lead: 16 parts of lead and one of antimony form an alloy which does not differ from lead except in hardneſs ¶. This alloy forms printers types.

9. Zinc and antimony form a brittle alloy, the ſpecific gravity of which is leſs than intermediate.* The alloys of antimony are little known. Gellert is almoſt the

‖ Fourcroy.
§ Kirwan's Miner. ii. 244.
¶ Bergman.
* Kirwan's Miner. ii. 489.
† Ibid.
‡ Rouelle.
§ Schrickel.
* Bergma iii. 167.
† Pelletier Ann. de Chim. xiii 132.
* Dr Lew
† Gellert.
‡ Id.
§ Id.
¶ Gmelin, Ann. de Chim. viii 319.
* Gellert.

(D) Muriatic acid decompoſes benzoat of antimony. *Trommſdorf, Ann. de Chim.* xi. 317.

the only perſon who has examined them. It would require a great number of experiments to be able to fix the proportions of their ingredients.

The affinities of antimony are, according to Bergman, as follows:

Iron,
Copper,
Tin,
Lead,
Nickel,
Silver,
Biſmuth,
Zinc,
Gold,
Platinum,
Mercury,
Arſenic,
Cobalt,
Sulphuret of arſenic,
Sulphur,
Phoſphorus ?

SECT. XI. *Of Biſmuth.*

THE ancients appear to have known nothing of biſmuth, nor do we know who diſcovered it; but it is firſt mentioned by George Agricola, who was born about the end of the 15th century.

148 operties biſmuth, Biſmuth is of a yellowiſh or reddiſh white colour, and almoſt deſtitute both of taſte and ſmell.

It is brittle. Its hardneſs is 6*. Its ſpecific gravity is 9,8227†. It melts at 460° Fahrenheit‡.

* *irwan.* † *riſſon.* ‡ *ewis.*

When heated in cloſe veſſels it ſublimes. When allowed to cool ſlowly after fuſion it cryſtallizes.

Biſmuth is not altered by water. When expoſed to the air it ſoon tarniſhes.

149 oxyds, When biſmuth is kept fuſed in contact with air, it is gradually oxydated. When heated red hot, it emits a very faint blue flame, and its oxyd evaporates in the form of a yellowiſh ſmoke. When this ſmoke is collected, it is found to conſiſt of a brown coloured powder. This is the *brown oxyd of biſmuth.* It is compoſed of about 94 parts of biſmuth, and 6 of oxygen*. Biſmuth decompoſes nitric acid with great rapidity, by attracting its oxygen. If the quantity of acid be conſiderable, it diſſolves the oxyd as it forms; but the greater part of it may be precipitated by diluting the acid with water. This precipitate, which is a white powder, is *white oxyd of biſmuth.* It is compoſed of about 84 parts biſmuth, and 16 of oxygen†.

* *irwan's iner.* ii. 9. † *id.*

The affinities of the oxyds of biſmuth are, according to Bergman, as follows:

Oxalic acid,
Arſenic,
Tartarous,
Phoſphoric,
Sulphuric,
Sebacic,
Muriatic,
Benzoic(E)?
Nitric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Pruſſic,
Carbonic,
Ammonia.

150 Sulphuret, Sulphur combines readily with biſmuth by fuſion. The ſulphuret of biſmuth is of a bluiſh grey colour, and cryſtallizes into beautiful tetrahedral needles. It is compoſed of 85 parts of biſmuth, and 15 of ſulphur‡.

‡ *Wenzel, Kirwan's Miner.* ii. 492.

151 Phoſphuret, There appears to be little affinity between biſmuth and phoſphorus. Mr Pelletier attempted to produce the phoſphuret of biſmuth by various methods without ſucceſs. When he dropped phoſphorus, however, into biſmuth in fuſion, he obtained a ſubſtance which did not apparently differ from biſmuth, but which, when expoſed to the blow-pipe, gave evident ſigns of containing phoſphorus. Phoſphuret of biſmuth, according to Pelletier, is compoſed of about 96 parts of biſmuth, and four of phoſphorus*.

* *Ann. de Chim.* xiii. 130.

152 Alloys, Biſmuth combines readily with moſt of the metals.

1. Equal parts of biſmuth and gold form a brittle alloy, nearly of the ſame colour with biſmuth†.

2. Equal parts of biſmuth and ſilver form alſo a brittle alloy, but leſs ſo than the laſt. The ſpecific gravity of both theſe is greater than intermediate‡.

3. The alloy of biſmuth and platinum is alſo very brittle. When expoſed to the air, it aſſumes a purple, violet, or blue colour. The biſmuth may be ſeparated by heat§.

† *Keir, Macquer's Dict.* ‡ *Ibid.* § *Dr Lewis.*

4. Mercury diſſolves biſmuth very eaſily. The amalgam is more fluid than pure mercury, and has the property of diſſolving lead and rendering it alſo fluid‖. It is capable, however, of cryſtallizing. The cryſtals are either octahedrons, lamellated triangles, or hexagons. They are compoſed of one part of biſmuth and two of mercury‡.

‖ *Cramer.* ¶ *Chim. Dijon,* i. 3.

5. The alloy of copper and biſmuth is not ſo red as copper.

6. Nothing is known concerning the alloy of iron and biſmuth.

7. Biſmuth and tin unite readily. A ſmall portion of biſmuth increaſes the brightneſs, hardneſs, and ſonorouſneſs of tin: It often therefore enters into the compoſition of the compound called *pewter.* Equal parts of tin and biſmuth form an alloy that melts at 280°: eight parts of tin, and one of biſmuth, melt at 390°: two parts of tin, and one of biſmuth, at 330°§.

§ *Dr Lewis.*

8. The alloy of lead and biſmuth is of a dark grey colour, a cloſe grain, but very brittle.

9. Biſmuth does not combine with zinc.

10. The alloy of antimony and biſmuth is unknown.

Biſmuth likewiſe enters into triple compounds with metals: Two parts of lead, three of tin, and five of biſmuth, form an alloy which melts at the heat of boiling water, which is 212°.

153 And affinities. The affinities of biſmuth, according to Bergman, are as follows:

Lead,
Silver,
Gold,
Mercury,

Antimony,

(E) Muriatic acid decompoſes benzoat of biſmuth.—*Trommſdorf, Ann. de Chim.* xi. 317.

Antimony,
Tin,
Copper,
Platinum,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phoſphorus ?

Sect. XII. *Of Arſenic.*

The word *arſenic* (αρσενικον) occurs firſt in the works of Dioſcorides, and of ſome other authors who wrote about the beginning of the Chriſtian era. It denotes in their works the ſame ſubſtance which Ariſtotle had called σανδαραχη (f), and his diſciple Theophraſtus αρρενικον, which is a reddiſh coloured mineral, compoſed of arſenic and ſulphur, uſed by the ancients in painting, and as a medicine.

The *white oxyd of arſenic*, or what is known in commerce by the name of arſenic, is mentioned by Avicenna in the 11th century; but at what period the metal called arſenic was firſt extracted from that oxyd is unknown. Paracelſus ſeems to have known it. It is mentioned by Schroeder in his Pharmacopœia publiſhed in 1649*.

* *Bergman*, ii. 278.

154 Properties of Arſenic,

Arſenic when pure is of a bluiſh white colour. It is exceedingly brittle. Its hardneſs is 7†. Its ſpecific gravity 8,310.‡.

When expoſed to the temperature of 354° in cloſe veſſels it ſublimes§, and cryſtallizes in regular tetrahedrons.

† *Kirwan's Miner.* ii. 254.
‡ *Bergman*, ii. 278.
§ *Ibid.*

155 Its oxyds,

It is not much altered by water. Boiling water, however, is capable of diſſolving and retaining $\frac{1}{10000}$th of arſenic; but that part of the metal is no doubt reduced to the ſtate of an oxyd||.

|| *Hahneman, Chim. Ann.* 1788, i. 182.

When arſenic is expoſed to the open air, it very ſoon loſes its luſtre, and is gradually converted into a greyiſh black ſubſtance by combining with oxygen. This is called the *grey oxyd of arſenic*.

When expoſed to a moderate heat in contact with air, it ſublimes in the form of a white powder, and at the ſame time emits a ſmell reſembling garlic. If the heat be increaſed, it burns with an obſcure bluiſh flame. This ſublimate is *white oxyd of arſenic*, which is compoſed of 93 parts of arſenic and 7 of oxygen¶.

¶ *Kirwan's Mineral.* ii. 490.

It is of a ſharp acrid taſte, which at laſt leaves an impreſſion of ſweetneſs, and is one of the moſt virulent poiſons known. It has an aliacious ſmell. It is ſoluble in 80 parts of water at the temperature of 60°, and in 15 parts of boiling water‡. When this ſolution is evaporated, the oxyd cryſtallizes.† When heated to 283°, it ſublimes: if heat be applied in cloſe veſſels, it becomes pellucid like glaſs, but when expoſed to the air, it ſoon recovers its former appearance. The ſpecific gravity of this glaſs is 5,000; that of the white oxyd, 3,706‡. This oxyd is capable of combining with moſt of the metals, and in general renders them brittle. Its affinities, according to Bergman, are as follows:

§ *Bergman*, ii. 278.
† *Brandt, Act. Upſal.* 1733.
‡ *Bergman*, ii. 278.

Muriatic acid,
Oxalic,
Sulphuric,
Nitric,
Sebacic,
Tartarous,
Phoſphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Arſenic,
Acetous,
Pruſſic,
Ammonia,
Water,
Alcohol ?

Arſenic, or rather the white oxyd of arſenic, is capable of combining with an additional doſe of oxygen. The compound produced is *arſenic acid*, firſt diſcovered by Scheele, which contains 91 parts of arſenic and 9 of oxygen*.

* *Berthol*
Kirwan's Miner. ii 490.

156 Sulphure

Arſenic combines readily with ſulphur. When heat is applied to a mixture of white oxyd of arſenic and ſulphur, the oxyd is decompoſed, part of the ſulphur combines with its oxygen, and the remainder unites with the reduced metal. The ſulphuret of arſenic produced by this proceſs is of a yellow colour, and was formerly called *orpiment*. It is compoſed, according to Weſtrum, of 20 parts of arſenic, and 80 of ſulphur†. It is often found native. If a ſtronger heat be applied, ſo as to melt the ſulphuret, it aſſumes a ſcarlet colour, and is much leſs volatile than formerly. This new compound was formerly called *realgar*. It is compoſed, according to Weſtrum, of 80 parts of arſenic, and 20 of ſulphur‡. The difference, therefore, between it and orpiment is evident. During the fuſion, part of the ſulphur without doubt ſublimes. It might be called *red ſulphuret of arſenic*.

† *Kirwa* *Miner.* ii 492.
‡ *Ibid.*

157 Phoſphuret,

Arſenic combines readily with phoſphorus. The phoſphuret of arſenic may be formed by diſtilling equal parts of its ingredients over a moderate fire. It is black and brilliant, and ought to be preſerved in water. It may be formed likewiſe by putting equal parts of phoſphorus and arſenic into a ſufficient quantity of water, and keeping the mixture moderately hot for ſome time§.

§ *Pelleti* *Ann. de* *Chim.* xi 139.

Arſenic unites with moſt metals, and in general renders them more brittle and more fuſible.

158 Alloys

1. Melted gold takes up $\frac{1}{60}$th of arſenic||. The alloy is brittle and pale.

|| *Bergm.* *ibid.*

2. Melted ſilver takes up $\frac{1}{14}$th of arſenic¶. The alloy is brittle.

¶ *Ibid.*

3. The alloy of platinum and arſenic is brittle and very fuſible. It was firſt formed by Scheffer. The arſenic may be ſeparated by heat.

4. The amalgam of arſenic is compoſed of five parts of mercury and one of arſenic§.

§ *Ibid.*

(f) Pliny ſeems to make a diſtinction between ſandaracha and arſenic. See Lib. xxxiv. c. 18.

5. Copper takes up $\frac{5}{6}$ths of arſenic†. This alloy is white; and when the quantity of arſenic contained in it is ſmall, both ductile and malleable†. It is called *white tombac*.

6. Iron is capable of combining with more than its own weight of arſenic§. This alloy is white, brittle, and capable of cryſtallizing. It is found native‖.

7. The alloy of tin and arſenic is harder and more ſonorous than tin, and has much reſemblance externally to zinc. Tin often contains a ſmall quantity of arſenic.

8. Lead takes up $\frac{1}{6}$th of arſenic¶. The alloy is brittle and dark coloured.

9. Zinc takes up $\frac{1}{5}$th of arſenic, antimony $\frac{1}{8}$th, and biſmuth $\frac{1}{15}$th.*

Ibid.
Gellert.
Bergman, nn. de him. xiii. 39.
Kirwan's iner. ii. 56.
Bergman, *id.*
Ibid.

159
nd affini- es.

The affinities of arſenic, according to Bergman, are as follows:

Nickel,
Cobalt,
Copper,
Iron,
Silver,
Tin,
Gold,
Platinum,
Zinc,
Antimony,
Sulphuret of alkali,
Sulphur,
Phoſphorus.

Sect. XIII. *Of Cobalt.*

A mineral called *cobalt* (G), of a grey colour, and very heavy, has been uſed in different parts of Europe ſince the 15th century to tinge glaſs of a blue colour. From this mineral Brandt obtained in 1733 a new metal, to which he gave the name of *cobalt*†.

Act. Up- l. 1733.

160
roperties cobalt,

Cobalt is of a white colour, inclining to a bluiſh or ſteel grey. When pure, it is ſomewhat malleable while red hot‡. Its hardneſs is 8§. Its ſpecific gravity is 8,15 (H). It requires for fuſion a heat at leaſt as great as caſt iron, which melts at 130° Wedgewood. No heat has been produced great enough to volatilize it‖.

Leonhardi.
Kirwan's iner. ii. 68.
Bergman,

Cobalt, when pure, does not ſeem to be affected by air or water.

It is attracted by the magnet.

161
Its oxyds,

It is not oxydated by heat without very great difficulty; but it has the property of decompoſing nitric acid, and of attracting oxygen by that means with great rapidity.

The *oxyd of cobalt* is of ſo deep a blue as to appear black. The oxyd procured by heat is compoſed of 88 parts of cobalt and 12 of oxygen; that by nitric acid contains about 77 parts of cobalt and 23 of oxygen.* Its affinities, according to Bergman, are as follows:

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phoſphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arſenic,
Boracic,
Pruſſic,
Carbonic,
Ammonia.

* *Kirwan's Miner.* ii. 268. 490.

162
Sulphuret,

The *ſulphuret of cobalt* is not formed without difficulty. It is ſcarcely known.

163
Phoſphuret,

Phoſphuret of cobalt may be formed by heating the metal red hot, and then gradually dropping in ſmall bits of phoſphorus. It contains about $\frac{1}{15}$th of phoſphorus. It is white and brittle, and when expoſed to the air ſoon loſes its metallic luſtre. The phoſphorus is ſeparated by heat, and the cobalt is at the ſame time oxydated. This phoſphuret is much more fuſible than pure cobalt†.

† *Pelletier, Ann. de Chim.* xiii. 134.

164
Alloys,

The combinations of cobalt with other metals have been very little examined into.

1. The alloy of gold and cobalt is not known.

2. Cobalt does not combine with ſilver by fuſion‡; but, according to Gellert, the alloy of ſilver and cobalt *may* be formed: it is brittle and of a grey colour§.

3. The alloy of platinum and cobalt is unknown.

4. Mer-

‡ *Bergman's Elect. Attract.*
§ *Metallur. Chim.*

(G) The word *cobalt* ſeems to be derived from *cobalus*, which was the name of a ſpirit that, according to the ſuperſtitious notions of the times, haunted mines, deſtroyed the labours of the miners, and often gave them a great deal of unneceſſary trouble. The miners probably gave this name to the mineral out of joke, becauſe it thwarted them as much as the ſuppoſed ſpirit, by exciting falſe hopes, and rendering their labour often fruitleſs; for as it was not known at firſt to what uſe the mineral could be applied, it was thrown aſide as uſeleſs. It was once cuſtomary in Germany to introduce into the church-ſervice a prayer that God would preſerve miners and their works from *kobalts* and ſpirits. See *Beckmann's Hiſtory of Inventions*, II. 362.

Matheſius, in his tenth ſermon, where he ſpeaks of *cadmia foſſilis* (probably cobalt ore), ſays, "Ye miners call it *kobolt;* the Germans call the black devil and the old devil's whores and hags, old and black *kobel*, which by their witchcraft do injury to people and to their cattle."

Lehmann, Paw, Delaval, and ſeveral other philoſophers, have ſuppoſed that *ſmalt* (oxyd of cobalt melted with glaſs and pounded) was known to the ancients, and uſed to tinge the beautiful blue glaſs ſtill viſible in ſome of their works; but we learn from Gmelin, who analyſed ſome of theſe pieces of glaſs, that they owed their *blue* colour, not to the preſence of *cobalt* but of *iron*.

According to Lehmann, cobalt ore was firſt uſed to tinge glaſs blue by Chriſtopher Schurer, a glaſs-maker at Plattan, about the year 1540.

(H) *Berg.* II. 231. According to Briſſon, 7,8119.

4. Mercury does not appear to amalgamate with cobalt.

5. The alloy of copper and cobalt is ſcarcely known.

6. The alloy of iron and cobalt is very hard, and not eaſily broken. Cobalt generally contains ſome iron, from which it is with great difficulty ſeparated.

7. The alloy of tin and cobalt is of a light violet colour.

8. Cobalt does not combine with lead by fuſion.

9. The alloy of zinc and cobalt is not formed without difficulty.

10. The alloy of antimony and cobalt is unknown.

11. Cobalt does not combine with biſmuth by fuſion.*

12. Arſenic combines very readily with cobalt. The alloy is brittle, much more fuſible, and more eaſily oxydated than pure cobalt†.

165
And affinities.

The affinities of cobalt are as follows:

Iron,
Nickel,
Arſenic,
Copper,
Gold,
Platinum,
Tin,
Antimony,
Zinc,
Sulphuret of alkali,
Sulphur,
Phoſphorus?

Sect. XIV. *Of Nickel.*

166
Diſcovery of nickel.

A heavy mineral of a red colour is met with in ſeveral parts of Germany, which bears a ſtrong reſemblance to an ore of copper; but none of that metal can be extracted from it: for this reaſon the Germans called it *kupſer nickel* (devil's copper.) Hierne mentioned it in 1694. Cronſtedt was the firſt chemiſt who examined it with accuracy. He concluded from his experiments, which were publiſhed in the Stockholm Tranſactions for 1751 and 1754 that it contained a new metal, to which he gave the name of *nickel.*

Some chemiſts, particularly Mr Sage, affirmed, that it contained no new metal, but merely a compound of various known metals, which could be ſeparated from each other by the uſual proceſſes. Theſe aſſertions induced Bergman to undertake a very laborious courſe of experiments, in order if poſſible to obtain *nickel* in a ſtate of purity: for Cronſtedt had not been able to ſeparate a quantity of arſenic, cobalt, and iron, which adhered to it with much obſtinacy. Theſe experiments have been very fully detailed in the article Chemistry in the *Encycl.* to which we beg leave to refer. Bergman has ſhewn, that nickel poſſeſſes peculiar properties, and that it can neither be reduced to any other metal, nor formed artificially by any combination of metals. It muſt therefore be conſidered as a peculiar metal. It may poſſibly be a compound, and ſo may likewiſe many other metals; but we muſt admit every thing to be a peculiar body which has peculiar properties, and we muſt admit every body to be ſimple till ſome proof be actually produced that it is a compound; otherwiſe we forſake the road of ſcience, and get into the regions of fancy and romance.

167
Its properties,

Nickel is of a greyiſh white colour, and when leſs pure inclines a little to red.

It is both ductile and malleable. Its hardneſs is 8*. Its ſpecific gravity 9,000†. It requires for fuſion a temperature at leaſt equal to 150° Wedgewood‡.

It is powerfully attracted by the magnet, and is even poſſeſſed of the property of attracting iron. This induced Bergman to ſuppoſe that nickel, when pureſt, was ſtill contaminated with about one-third of iron: but as this is the only proof of its containing iron, Klaproth, with reaſon, deems it an inſufficient one, and conſiders attraction by the magnet as a property of nickel§.

168
Oxyds,

When expoſed to a ſtrong heat, nickel is oxydated ſlowly. Its oxyd is of a *brown* colour; if impure, it is *greeniſh*. The oxyd of nickel, according to Klaproth, is compoſed of 77 parts of nickel and 33 of oxygen¶. Its affinities, according to Bergman, are as follows:

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phoſphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arſenic,
Boracic,
Pruſſic,
Carbonic,
Ammonia,
Potaſs?
Soda?

169
Sulphuret,

Cronſtedt found that nickel combined readily with ſulphur by fuſion. The ſulphuret which he obtained was yellow and hard, with ſmall ſparkling facets; but the nickel which he employed was impure.

170
Phoſphuret,

Nickel combines very readily with phoſphorus, either by fuſing it along with phoſphoric glaſs, or by dropping phoſphorus into it while red hot. The phoſphuret of nickel is of a white colour, and when broke exhibits the appearance of very ſlender priſms collected together. When heated, the phoſphorus burns, and the metal is oxydated. It is compoſed of 83 parts of nickel and 17 of phoſphorus*. The nickel, however, on which this experiment was made, was not pure.

171
Alloys,

Little is known concerning the alloys of nickel with other metals. Equal parts of ſilver and nickel form a white ductile alloy. Equal parts of copper and nickel form a red ductile alloy. The compounds which this metal forms with tin and zinc are brittle. It does not combine with mercury†. It has a very ſtrong affinity for iron, cobalt, and arſenic, and is ſcarcely ever found except combined with ſome of them.

172
And affinities.

Its affinities, according to Bergman, are as follows:

Iron,
Cobalt,
Arſenic,

Copper,

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* Baumé.

† Bergman, iv.

* Kirwan Miner. ii. 281.

† Bergman ii. 231.

‡ Ibid.

§ Ann. de Chim. i. 170.

¶ Kirwan Miner. ii. 490.

* Pelletier, Ann. de Chim. xiii. 135.

† Bergman, ii. 231.

Silver,
Tin,
Sulphuret of alkali,
Phoſphorus ?
Carbon ?

The three metals, *cobalt*, *nickel*, and *manganeſe*, reſemble iron in ſeveral particulars: Like it they are magnetic, very hard, and very difficult to fuſe: but they differ from it in ſpecific gravity, malleability, and in the properties of all their combinations with other ſubſtances; the oxyds, for inſtance of iron, cobalt, nickel, and manganeſe, poſſeſs very different qualities.

SECT. XVI. *Of Tungſten.*

180 Diſcovery of tungſten,

THERE is a mineral found in Sweden of an opaque white colour, and great weight; from which laſt circumſtance it got the name of *tungſten*, or *ponderous ſtone*. Some mineralogiſts conſidered it as an ore of tin, others ſuppoſed that it contained iron. Scheele analyſed it in 1781, and found that it was compoſed of lime and a peculiar earthy-like ſubſtance, which he called from its properties *tungſtic acid*. Bergman conjectured that the baſis of this acid was a metal; and this conjecture was ſoon after fully confirmed by the experiments of Meſſrs D'Elhuyart, who obtained the ſame ſubſtance from a mineral of a browniſh black colour, called by the Germans *wolfram*, which is ſometimes found in tin mines. This mineral they found to contain $\frac{65}{100}$ of tungſtic acid; the reſt of it conſiſted of manganeſe, iron and tin. This acid ſubſtance they mixed with charcoal powder, and heated violently in a crucible On opening the crucible after it had cooled, they found in it a button of metal of a dark brown colour, which crumbled to powder between the fingers. On viewing it with a glaſs, they found it to conſiſt of a congeries of metallic globules, ſome of which were as large as a pin head. The metal thus obtained is called *tungſten*. The manner in which it was produced is evident; tungſtic acid is compoſed of oxygen and tungſten: the oxygen combined with the carbon, and left the metal in a ſtate of purity.

181 Its properties.

Tungſten is externally of a brown colour, internally of a ſteel grey*.

Its ſpecific gravity is 17,600‡. It is more infuſible than manganeſe‖.

When heat is applied to tungſten it is converted into a yellow powder, compoſed of 80 parts of tungſten and 20 of oxygen†. This is the *yellow oxyd of tungſten* or *tungſtic acid*.

The ſulphuret of tungſten is of a bluiſh black colour, hard, and capable of cryſtallizing.

Phoſphorus is capable of combining with tungſten§.

Of the alloys of tungſten we know nothing, except from the experiments of Elhuyarts, which have been tranſcribed into the article chemiſtry in the *Encyclopædia*; to which, therefore, we beg leave to refer.

SECT. XVII. *Of Molybdenum.*

182 Diſcovery of molybdenum.

THE Greek word *molybdena*, and its Latin tranſlation *plumbago*, ſeem to have been employed by the ancients to denote various oxyds of lead; but by the moderns they were applied indiſcriminately to all ſubſtances poſſeſſed of the following properties: Light, friable, and ſoft, of a dark colour and greaſy feel, and which leave a ſtain upon the fingers. Scheele firſt examined theſe minerals with attention. He found, that two very different ſubſtances had been confounded together. To one of theſe, which is compoſed of carbon and iron, and which has been already deſcribed, he appropriated the word *plumbago*; the other he called *molybdena*.

Molybdena is compoſed of ſcaly particles adhering ſlightly to each other. Its colour is bluiſh, very much reſembling that of lead. Scheele analyſed it, and obtained ſulphur and a whitiſh powder, which poſſeſſed the properties of an acid, and which, therefore, he called *acid of molybdena*. Bergman firſt ſuſpected that the baſis of this acid was a metal. It was at the requeſt of Bergman and Scheele that Mr Hielm began the laborious courſe of experiments by which he ſucceeded in obtaining a metal from this acid. His method was to form it into a paſte with linſeed oil, and then to apply a very ſtrong heat. This proceſs he repeated ſeveral times ſucceſſively. Klaproth and Pelletier alſo attempted to reduce it, and with equal ſucceſs. The metal is *molybdenum*(K).

183 Its properties.

Molybdenum is externally of a whitiſh yellow colour, but its fracture is a whitiſh grey.

Hitherto it has only been procured in ſmall grains, agglutinated together in brittle maſſes.

Its ſpecific gravity is 7,500. It is almoſt infuſible in our fires.

When expoſed to a ſtrong heat, it is gradually converted into a whitiſh-coloured oxyd‡. When nitric acid is poured upon it, molybdenum attracts oxygen, and is converted into a *white oxyd*, which poſſeſſes the properties of an acid†. This is the *molybdic acid*.

Molybdenum combines readily with ſulphur; and the compound has exactly the properties of molybdena, the ſubſtance which Scheele decompounded§. Molybdena is therefore *ſulphuret of molybdenum*. The reaſon that Scheele obtained from it molybdic acid was, that the metal combined with oxygen during his proceſs.

Molybdenum is alſo capable of combining with phoſphorus*.

Few of the alloys of this metal have been hitherto examined.

It ſeems capable of uniting with gold. The alloy is probably of a white colour‡.

It combines readily with platinum while in the ſtate of an oxyd. The compound is fuſible. Its ſpecific gravity is 20,00§.

The alloys of molybdenum with ſilver, iron and copper, are metallic and friable; thoſe with lead and tin are powders which cannot be fuſed*.

SECT. XVIII. *Of Uranium.*

184 Diſcovery of uranium.

THERE is a mineral found in the George Wagsfort mine at Johann-Georgenſtadt in Saxony, partly in a pure or unmixed ſtate, and partly ſtratified with other kinds of ſtones and earths. The firſt variety is of a blackiſh colour inclining to a dark iron grey, of a moderate ſplendor, a cloſe texture, and when broken preſent a ſomewhat uneven, and, in the ſmalleſt particles, a conchoidal ſurface. It is quite opaque, tolerably hard, and on being pounded yields a black powder. Its ſpecific gravity is about 7,500. The ſecond ſort is diſtinguiſhed by a finer black colour, with here and there a reddiſh caſt; by a ſtronger luſtre, not unlike that of pitcoal; by an inferior hardneſs; and by a ſhade of green, which tinges its black colour when it is reduced to powder.*

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* Luyart.
‡ Id.
‖ Id.
† Id.
§ Pelletier, Ann. de Chim. xiii. 137.

‡ Pelletie Journ. de Phyſ. 17
† Ibid.
§ Ibid.
* Pelletie Ann. de Chim. xii 137.
‡ Ruprech Ann. de Chim. vii 8.
§ Hielm, Ann. de Chim. iv. 17.
* Pelletie Journal d Phyſique, Dec. 17

(K) This name was given it by Hielm.

This foſſile was called *pechblende;* and mineralogiſts, miſled by the name (L), had taken it for an ore of zinc, till the celebrated Werner, convinced from its texture, hardneſs, and ſpecific gravity, that it was not a *blende*, placed it among the ores of iron. Afterwards he ſuſpected that it contained *tungſten;* and this conjecture was ſeemingly confirmed by the experiments of ſome German mineralogiſts, publiſhed in the Miners Journal ‡. But Klaproth, whoſe analyſes always diſplay the moſt conſummate ſkill, joined with the moſt rigid accuracy, examined this mineral about the year 1789, and found that it conſiſted chiefly of ſulphur combined with a peculiar metal, to which he gave the name of *uranium* (M).

185
Iproper-
ti.

Uranium is of a dark grey colour; internally it is ſomewhat inclined to brown ‡.

Its malleability is unknown. Its hardneſs is about 6. It requires a ſtronger heat for fuſion than manganeſe. Indeed Klaproth only obtained it in very ſmall conglutinated metallic grains, forming altogether a porous and ſpongy maſs.—Its ſpecific gravity is 6,440 ‖.

When expoſed for ſome time to a red heat, it ſuffers no change. By means of nitric acid, however, it may be converted into a yellow powder. This is the *yellow oxyd of uranium.* This oxyd is found native mixed with the mineral above deſcribed. Its affinities have not yet been determined.

Uranium is capable of combining with ſulphur. The mineral from which Mr Klaproth firſt obtained it is a native ſulphuret of uranium.

Nothing is known concerning the alloys or affinities of uranium.

SECT. XIX. *Of Titanium.*

186
Dovery
ofitani-

THERE is a mineral found in Hungary which, from its external appearance, has been called *red ſhorl;* but Klaproth, who examined it about the year 1795, diſcovered that it conſiſted chiefly of a peculiar metal, to which he gave the name of *titanium.*

187
It roper-

Titanium is of a browniſh red colour, and conſiderable luſtre. It is brittle. Its hardneſs is 9; its ſpecific gravity 4,18.

When expoſed to a ſtrong heat in a clay crucible, it ſuffered no alteration, except that its colour became browner; but in a coal crucible it loſt its luſtre and broke to pieces.

It is found naturally cryſtallized in right-angled quadrangular priſms, longitudinally furrowed, and about ½ inch in length.

No acid had any effect in oxydating it; but when mixed with five times its weight of potaſs, and heated in a porcelain furnace, it melted, and formed when cold a denſe greyiſh maſs, the ſurface of which was cryſtallized. When diſſolved in boiling water, it ſoon let fall a white powder, weighing about one-third more than the titanium employed. This is the *oxyd of titanium.* Fifty grains of it were reduced by ignition to 38. While hot it was yellowiſh, but, like oxyd of zinc, became white as it cooled. When heated on charcoal, it aſſumes firſt a *roſy red,* and afterwards a *ſlate blue* colour, and at laſt melts into an imperfect bead with a finely ſtriated ſurface. Mr Klaproth did not ſucceed in reducing it to the metallic ſtate.

Titanium does not ſeem to have any affinity for ſulphur †.

188
Menachanite.

There was a ſubſtance diſcovered by Mr M'Gregor in the valley of Menachan in Cornwall, and hence called *menachanite.* Upon this ſubſtance Mr M'Gregor made a very intereſting ſet of experiments, which were publiſhed in the Journal de Phyſique for 1791. He ſuſpected it to contain a new metal. From its properties, Mr Kirwan conjectured that it was the ſame with titanium;* and this conjecture has been very lately confirmed by Mr Klaproth, who analyſed menachanite, and found it to be an ore of that metal.

SECT. XX. *Of Tellurium.*

189
Diſcovery
of tellurium.

IN the mountains of Fatzbay, near Zalethna in Tranſylvania, there is a mine called *Mariahilf;* the ore of which is wrought for the gold that it contains. Mr Muller of Reichenſtein examined it in 1782, and ſuſpected that it contained a new metal; and Bergman, to whom he had ſent ſome of the ore, was of the ſame opinion: but the quantity of the mineral which theſe chemiſts had examined was too inconſiderable to enable them to decide with certainty. Klaproth analyſed a larger quantity of it about the year 1797, and found that 1000 parts of it conſiſted of 72 parts of iron, 2,5 of gold, and 925,5 of a new metal, to which he has given the name of *tellurium* (N).

190
Its properties.

Tellurium is of a white colour like tin, approaching ſomewhat to the grey colour of lead.*

It is very brittle and friable. Its fracture is laminated. Its ſpecific gravity is 6,115.

It is as eaſily melted as lead. When ſuffered to cool quietly and gradually, it readily aſſumes a cryſtallized ſurface †.

When heated by the blowpipe upon charcoal, it burns with a very lively flame of a blue colour, inclining at the edges to green. It is ſo volatile as to riſe entirely in a whitiſh grey ſmoke; at the ſame time it exhales a diſagreeable odour like that of radiſhes. This ſmoke is the *white oxyd* of tellurium, which may be formed alſo by diſſolving the metal in nitro-muriatic acid, and pouring into the ſaturated ſolution a quantity of water: a white powder precipitates, which is the oxyd ‡.

When this oxyd is heated for ſome time in a retort, it melts, and appears, after cooling, of a yellow ſtraw colour, having acquired a ſort of radiated texture. When formed

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Klaproth,
ell's Jour-
, Eng.
nſl. i.
6.

id.

id. 233.

id.

† M'Gregor.

* Mineral. ii. 331.

* Klaproth, Philoſophical Magazine, i. 78.

† Muller.

‡ Klaproth.

(L) *Blende* is the name given to ores of zinc.

(M) From *Uranus* (Ουρανος), the name given by Mr Bode to the new planet diſcovered by Herſchel; which name the German aſtronomers have adopted. Mr Klaproth called the metal at firſt *uranite;* but he afterwards changed that name for *uranium.*

(N) Mr Kirwan, in the new edition of his Mineralogy, which was publiſhed before Mr Klaproth's experiments were known, gives this metal the name of *Sylvanite.*—Tellurium exiſts in ſeveral other mines in the ſame mountains.

Tellurium.

formed into a paſte with any fat oil, and diſtilled in a red heat, brilliant metallic drops are obſerved to cover the upper part of the retort, which at intervals fall to the bottom of the veſſel, and are immediately replaced by others. After cooling, metallic fixed drops are found adhering to the ſides and at the bottom of the veſſel; the remainder of the metal is reduced. Its ſurface is brilliant and almoſt always cryſtallized. When this oxyd is expoſed to heat on charcoal, it is reduced with a rapidity that reſembles detonation.*

Tellurium combines with ſulphur. The ſulphuret of this metal is of a grey colour and radiated ſtructure. When placed on red hot charcoal, the metal burns as well as the ſulphur with a blue flame.

Tellurium amalgamates with mercury by ſimple trituration§.—The other properties of this metal are unknown.

191 Chrom

A NEW metal has lately been diſcovered by Vauquelin in the red lead ore of Siberia. It is grey, very hard, brittle, and eaſily cryſtallizes in ſmall needles†. He has given it the name of *chromum* (o).

We have now deſcribed all the metals at preſent known. The following table will exhibit in one view their principal properties.

192 General table of propert of the tals.

Metals.	Colour.	Hardneſs.	Specific Gravity.	Fuſing Point.	Malleability.	Ductility	
Gold.	Yellow.	6	19,300	32 W. (p) 1298 F.	282000	500	
Silver.	White.	6½	10,510	28 W. 1044 F.	160000	270	
Platinum.	White.	7½	23,000	150 W.?		above 500	
Mercury.	White.		13,568	—39 F.			
Copper.	Red.	8	8,870	27 W. 1449 F.		299¼	
Iron.	Blue-grey.	9	7,788	150 W. 20577 F.		450	Magnetic.
Tin.	White.	6	7,299	410 F.	2000	49	
Lead.	Blue-white.	5	11,352	540 F.		29¼	
Zinc.	White.	6	7,190	700 F.		0	
Antimony.	Grey.	6½	6,860	700 F.	0	0	
Biſmuth.	Yellow-white.	6	9,822	460 F.	0	0	
Arſenic.	White.	7	8,310	400 F. ?	0	0	
Cobalt.	White.	8	8,150	130 W. 17977 F.			Magnetic.
Nickel.	White.	8	9,000	150 W. 20577 F.			Magnetic.
Manganeſe.	White.	8	7,000	150 W. 20577 F.	0	0	Magnetic.
Tungſten.	Brown.	6	17,600		0	0	
Molybdenum.	Grey.		7,500		0	0	
Uranium.	Grey.	6	6,440				
Titanium.	Red.	9	4,180		0	0	
Tellurium.	White.		6,115	540 F.	0	0	
Chromum.	Grey.				0	0	

(o) From χρωμα, becauſe it poſſeſſes the property of giving colour to other bodies in a remarkable degree.

(p) W. Wedgewood's pyrometer. F. Fahrenheit's thermometer.

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* Klaproth.

§ Mulle

† Nichol Journal. 146.

193
emarks
n metallic
xyds.

We have ſeen that all the metals are capable of combining with oxygen; that almoſt every one forms various oxyds, containing different quantities of oxygen, and varying in colour and other properties according to the proportion of oxygen which they contain. No part of chemiſtry has more engaged the attention of philoſophers than the metallic oxyds; and yet ſuch is the difficulty of the ſubject, that ſcarcely any part of chemiſtry is more imperfectly underſtood.

We neither know how many oxyds every particular metal is capable of forming, nor the manner in which they are formed: neither have the differences between oxyds of the ſame metallic baſe been enquired into; though there cannot be a doubt that they differ, not only in their affinities, but in many of their other properties. The *white oxyd* of mangaueſe, for inſtance, combines readily with acids, but the *black* is incapable of uniting with any.

Mr Prouſt, in a very valuable paper which he lately publiſhed concerning the oxyds of iron[*], hints that metals are only capable of two degrees of oxydation, or, which is the ſame thing, that only two different oxyds can be produced from the ſame metal. We think he has proved this completely as far as iron is concerned; and probably the obſervation holds good with reſpect to many other metals. Arſenic, copper, tin, molybdenum, and perhaps even mercury, ſeem to be capable of only two degrees of oxydation; but it would require a very numerous and accurate ſet of experiments to be able to determine the matter, or even to form a probable conjecture. Analogy is certainly againſt the ſuppoſition; for it has been demonſtrated that ſome ſubſtances at leaſt are capable of combining with three different doſes of oxygen (q), and why may not this be the caſe alſo with the metals? (11).

There is one obſervation, however, which we owe to Mr Prouſt, the truth of which cannot be doubted, and which is certainly of the higheſt importance—that metals are not capable of indefinite degrees of oxydation, but only of a certain number; and that every particular oxyd conſiſts of a determinate quantity of the metal and of oxygen chemically combined. Iron, for inſtance, is not capable, as has been ſuppoſed, of uniting with oxygen in all the intermediate degrees between $\frac{27}{100}$ and $\frac{48}{100}$, and conſequently of forming 20 or 30 different oxyds; it can only combine with preciſely $\frac{27}{100}$ parts, or $\frac{48}{100}$ parts, and with no other proportions; and therefore is only capable of forming two oxyds, the *green* and the *brown*. In like manner, every other metal combines with certain proportions of oxygen, and forms either two oxyds or more according to its nature. To talk therefore of oxydating a metal indefinitely is not accurate, except it be intended to ſignify the combining of part of it with oxygen, while the reſt remains in its natural ſtate. If iron be oxydated at all, it muſt be combined with $\frac{27}{100}$ of oxygen; if it be oxydated more than this, it muſt be combined with $\frac{48}{100}$ of oxygen.

We beg leave to add another obſervation, which we conſider as of no leſs importance, and which will ſerve in ſome meaſure to modify and explain what has been juſt now ſaid. Oxygen is capable of uniting with metals, or with any other ſubſtance for which it has an affinity, only in *one* determinate proportion. Iron, for inſtance, and oxygen can only combine in the proportion of 73 parts of iron and 27 of oxygen. Theſe two quantities ſaturate each other, and form a compound which is incapable of receiving into it any more oxygen or iron: this compound is the *green oxyd of iron*. How comes it then, it will be aſked, that there is another oxyd of iron, the *brown oxyd*, which contains 52 parts of iron and 48 of oxygen, proportions certainly very different from 73 and 27? We anſwer, there is an affinity between the green oxyd of iron and oxygen; they are capable of combining together, and of ſaturating each other in the proportion of about 71,5 parts of green oxyd and 28,5 of oxygen; and the compound which they form is the *brown oxyd*, which of courſe contains 52 parts of iron and 48 of oxygen: But then it is not formed by the combination of theſe two ſubſtances directly, but by the combination of the green oxyd and oxygen. In like manner, the arſenic acid is not compoſed of arſenic and oxygen combined directly, but of white oxyd of arſenic combined with oxygen. The very ſame thing takes place in all the other metals. We cannot at preſent prove the truth of this obſervation in a ſatisfactory manner, becauſe it would be neceſſary to draw our proofs from combinations which are yet undeſcribed; but we will have occaſion to conſider it afterwards (12).

We have ſeen, that all the metals hitherto tried are capable of combining with ſulphur, except gold and titanium; that all of them on which the experiments have been made can be united with phoſphorus; and that three of them, iron, zinc, and mangancſe, united with carbon; and perhaps many more of them may hereafter be found capable of aſſuming the form of carburets.

We have ſeen, too, that they are capable of uniting with one another and forming alloys. This was long reckoned peculiar to metals, and it is at preſent one of the beſt criterions for determining the metallic nature of any ſubſtance. Much is wanting to render the chemiſtry of alloys complete. Many of them have never been examined; and the proportions of almoſt all of them are unknown. Neither has any accurate method been yet diſcovered of determining the affinities of metals for each other. The order of affinities which we have given for each metal was determined by Bergman; but he acknowledged himſelf that he wanted the proper data to enſure accuracy.

CHAP.

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[*] Ann. de Chim. xxiii. 85.—Nicholſon's Journ. i. 453.

(q) We ſhall ſee afterwards that azot is one of theſe.

(11) When we oxyd any metal in a *low* temperature, it goes regularly on, combining with freſh portions of oxygen until it is ſaturated. How can we make this fact accord with the theory of each of the metals being capable of exiſting in but two degrees of oxydation? Will it be ſufficient to ſay that the freſh portions of oxygen unite to freſh portions of the metal? Or would this account for the various colours ſome metals aſſume in the courſe of oxydation? T. P. S.

(12) As this fanciful theory is founded on deductions from "combinations which are yet undeſcribed," we ſhall wait till we meet with them before we enter on its examination. T. P. S.

CHAP. IV. *Of* EARTHS.

The word *earth*, in common language, has two meanings; it ſometimes ſignifies the *globe* which we inhabit, and ſometimes the *mould* on which vegetables grow. Chemiſts have examined this mould, and have found that it conſiſts of a variety of ſubſtances mixed together without order or regularity. The greateſt part of it, however, as well as of the ſtones, which form apparently ſo large a proportion of the globe, conſiſts of a ſmall number of bodies, which have a variety of common properties. Theſe bodies chemiſts have agreed to claſs together, and to denominate *earths*.

Every body which poſſeſſes the following properties is an *earth:*

194 Properties of earths.

1. Inſoluble in water, or nearly ſo; or at leaſt becoming inſoluble when combined with carbonic acid.
2. Little or no taſte or ſmell; at leaſt when combined with carbonic acid.
3. Incombuſtible, and incapable while pure of being altered by the fire.
4. A ſpecific gravity not exceeding 4,9.
5. When pure, capable of aſſuming the form of a white powder.

The earths at preſent known amount to eight; the names of which are, lime, magneſia, barytes, ſtrontites, alumina, ſilica, jargonia, glucina.

Every one of the above characteriſtics is not perhaps rigorouſly applicable to each of theſe bodies; but all of them poſſeſs a ſufficient number of common properties to render it uſeful to arrange them under one claſs.

SECT. I. *Of Lime.*

LIME has been known from the earlieſt ages. The ancients employed it in medicine: it was the chief ingredient in their mortar; and they uſed it as a manure to fertilize their fields.

195 Method of procuring lime.

It abounds in many parts of the world, or perhaps we ſhould rather ſay, that there is no part of the world where it does not exiſt. It is found pureſt in limeſtones, and marbles and chalk. None of theſe ſubſtances, however, is, ſtrictly ſpeaking, lime; but they are all capable of becoming lime by a well-known proceſs, by keeping them for ſome time in a white heat: this proceſs is called *the burning of lime;* the product is denominated *quicklime*. This laſt ſubſtance is what we call *lime*.

196 Properties of lime.

Pure lime is of a white colour, moderately hard, but eaſily reduced to a powder.

It has a hot burning taſte, and in ſome meaſure corrodes and deſtroys the texture of thoſe animal bodies to which it is applied. It has no ſmell. Its ſpecific gravity is 2,3*.

If water be poured on newly burnt lime, it ſwells and falls to pieces, and is ſoon reduced to a very fine powder. In the mean time, ſo much heat is produced, that part of the water flies off in vapour. If the quantity of lime ſlacked (as this proceſs is termed) be great, the heat produced is ſufficient to ſet fire to combuſtibles. In this manner, veſſels loaded with lime have ſometimes been burnt. When great quantities of lime are ſlacked in a dark place, not only heat, but light alſo is emitted, as Mr Pelletier has obſerved §. When ſlacked lime is weighed, it is found to be heavier than it was before. This additional weight is owing to the combination of part of the water with the lime; which water may be ſeparated again by the application of a red heat; and by this proceſs the lime becomes juſt what it was before being ſlacked||.

197 Lime-water.

Six hundred parts of water, at the temperature of 60°, diſſolve about one part of lime; boiling hot water diſſolves about double that quantity*. This ſolution is called *lime-water*. It is limpid, has an acrid taſte, and changes vegetable blue colours to green. One ounce troy of lime-water contains about one grain of lime.

One thouſand parts of lime are capable of abſorbing, and retaining, at a heat of 600°, 228 parts of water§.

Lime has never yet been obtained in the ſtate of cryſtals.

It is incapable of being fuſed by the moſt violent heat that can be produced in furnaces, or even by the moſt powerful burning glaſſes.

198 Sulphuret and

Lime unites readily with ſulphur, and forms *ſulphuret of lime*. This compound may be obtained by mixing unſlacked lime and flowers of ſulphur together, and adding a little water. The heat produced by the ſlacking of the lime is ſufficient to make the ſulphur and the lime unite. This ſulphuret is of a red colour. When water is poured on it, ſulphurated hydrogen gas is emitted. The ſulphur is gradually converted into ſulphuric acid by uniting with the oxygen of the water, the hydrogen of which flies off in the form of gas, diſſolving at the ſame time a part of the ſulphur.

199 Phoſphure of lime.

It is capable alſo of combining with phoſphorus.—The phoſphuret of lime decompoſes water by the aſſiſtance of a moderate heat, and gives out phoſphurated hydrogen gas.

200 Cauſe of the difference between lime ſtone and lime,

Limeſtone and chalk, though they are capable of being converted into lime by *burning*, poſſeſs hardly any of the properties of that active ſubſtance. They are taſteleſs, ſcarcely ſoluble in water, and do not perceptibly act on animal bodies. Now, to what are the new properties of lime owing? What alteration does it undergo in the fire?

201 According to Stahl;

It had been long known, that limeſtone loſes a good deal of weight by being burned or *calcined*. It was natural to ſuppoſe, therefore, that ſomething was ſeparated from it during calcination. Accordingly, Van Helmont, Ludovicus, and Macquer, made experiments in ſucceſſion, in order to diſcover what that *ſomething* was; and they concluded from them that it was *pure water*, which the lime recovered again when expoſed to the atmoſphere. As the new properties of lime could hardly be aſcribed to this loſs, but to ſome other cauſe, Stahl's opinion, like all the other chemical theories of that wonderful man, was generally acceded to. He ſuppoſed that the new properties, which lime acquired by calcination, were owing entirely to the more minute diviſion of its particles by the action of the fire. Boyle indeed had endeavoured to prove, that theſe properties were owing to the *fixation of fire* in the lime; a theory which was embraced by Newton and illuſtrated by Hales, and which Meyer new modelled, and explained with ſo much ingenuity and acuteneſs as to draw the attention of the moſt diſtinguiſhed chemiſts. But while Meyer was thus employed in Germany, Dr Black of Edinburg publiſhed thoſe celebrated experiments which form ſo brilliant an era in the hiſtory of chemiſtry.

202 Explained by Dr Black

He firſt aſcertained that the quantity of water ſeparated from limeſtone during its calcination was not nearly

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* *Kirwan's Miner.* i. 5.

|| *Jour. de Phyſ.* t. 22.

|| *Dr Bla*

* *Kirwan Miner.* i.

§ *Lavoiſie*

ly equal to the weight which it loſt. He concluded in conſequence, that it muſt have loſt ſomething elſe than mere water. What this could be, he was at firſt at a loſs to conceive; but recollecting that Dr Hales had proved, that limeſtone, during its ſolution in acids, emitted a great quantity of *air*, he conjectured that *this* might probably be what it loſt during calcination. He calcined it accordingly, and applied a pneumatic apparatus to receive the product. He found his conjecture verified; and that the *air* and *the water* which ſeparated from the lime, were together preciſely equal to the loſs of weight which it had ſuſtained. Lime therefore owes its new properties to the loſs of *air;* and limeſtone differs from lime merely in being combined with a certain quantity of *air:* for he found that, by reſtoring again the ſame quantity of *air* to lime, it was converted into limeſtone. This air, becauſe it exiſted in lime in a fixed ſtate, he called *fixed air*. It was afterwards examined by Dr Prieſtley and other philoſophers, found to poſſeſs peculiar properties, and to be that ſpecies of gas now known by the name of *carbonic acid gas*. Lime then is a ſimple ſubſtance, that is to ſay, it has never yet been decompounded; and limeſtone is compoſed of carbonic acid and lime. Heat ſeparates the carbonic acid, and leaves the lime in a ſtate of purity.

203 finities lime.

The affinities of lime, according to Bergman, are as follows:

Oxalic acid,
Suberic (R)?
Sulphuric,
Tartarous,
Succinic,
Phoſphoric,
Saccholactic,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Arſenic,
Formic,
Lactic,
Citric,
Benzoic,
Sulphurous,
Acetous,
Boracic,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus,
Water,
Fixed oil.

SECT. II. *Of Magneſia.*

204 I:overy o nagneſi

ABOUT the beginning of the eighteenth century, a Roman canon expoſed a white powder to ſale at Rome as a cure for all diſeaſes. This powder he called *magneſia alba*. He kept the manner of preparing it a profound ſecret; but in 1707 Valentini informed the public that it might be obtained by calcining the lixivium which remains after the preparation of nitre; and two years after, Slevogt diſcovered that it might be precipitated by potaſs from the mother ley (S) of common ſalt. This powder was generally ſuppoſed to be *lime*, till Frederic Hoffman obſerved that it formed very different combinations with other bodies.* But little was known concerning its nature till Dr Black publiſhed his celebrated experiments in 1755. Margraf publiſhed a diſſertation on it in 1759, and Bergman another in 1775, in which he collected the obſervations of theſe two philoſophers, and which he enriched alſo with many additions of his own.

* *Bergman*, i. 365.

205 Method of procuring it.

As magneſia has never yet been found native in a ſtate of purity, it may be prepared in the following manner: *Sulphat of magneſia*, a ſalt compoſed of this earth and ſulphuric acid, exiſts in ſea water, and in many ſprings, particularly ſome about Epſom, from which circumſtance it was formerly called *Epſom ſalt*. This ſalt is to be diſſolved in water, and half its weight of potaſs added. The magneſia is immediately precipitated, becauſe potaſs has a ſtronger affinity for ſulphuric acid. It is then to be waſhed with a ſufficient quantity of water, and dried.

206 Its properties.

Magneſia thus obtained is a very ſoft white powder, which has very little taſte, and is totally deſtitute of ſmell.—Its ſpecific gravity is about 2,3 §.

It is ſoluble in about 7900 times its own weight of water at the temperature of 60° ||.

§ *Kirwan's Miner.* i. 8.

|| *Ibid.*

Even when combined with carbonic acid (for which it has a ſtrong affinity) it is capable of abſorbing and retaining 1½ times its own weight of water, without letting go a drop; but on expoſure to the air, this water evaporates, though more ſlowly than it would from lime.

Magneſia has never yet been obtained in a cryſtallized form.

It tinges vegetable blues of an exceedingly ſlight green.

It is not melted by the ſtrongeſt heat which it has been poſſible to apply; but Mr D'Arcet obſerved that, in a very high temperature, it became ſomewhat agglutinated.

When magneſia and ſulphur are put into a veſſel of water, and kept for ſome time expoſed to a moderate heat, they combine, and form ſulphuret of magneſia; which, according to Fourcroy, is capable of cryſtallizing.

The phoſphuret of magneſia has never been examined.

207 Effect of heat on mixtures of lime and magneſia.

Equal parts of lime and magneſia mixed together, and expoſed by Lavoiſier to a very violent heat, did not melt; neither did they melt when Mr Kirwan placed them in the temperature of 150° Wedgewood.—The following

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(R) The affinity of this acid for lime is inferior to the oxalic, which decompoſes the ſuberat of lime. *Jameſon's Mineral. of Shetland and Arran*, p. 168.

(S) *The mother ley* is the liquid that remains after as much as poſſible of any ſalt has been obtained from it. Common ſalt, for inſtance, is obtained by evaporating ſea water. After as much ſalt has been extracted from a quantity of ſea water as will cryſtallize, there is ſtill a portion of liquid remaining. This portion is the mother ley.

following table, drawn up by Mr Kirwan from his own experiments, ſhews the effect of heat on theſe two earths mixed together in different proportions,

Proportions.	Heat.	Effect.
80 Lime 20 Mag.	150° Wedg.	Went through the crucible.
75 Lime 25 Mag.	160	Went through the crucible.
66 Lime 33 Mag.		Went through the crucible.
20 Lime 80 Mag.	165	Did not melt.
33 Lime 66 Mag.	138	Did not melt.
30 Lime 10 Mag.	156	Melted into a fine greeniſh yellow glaſs ; but the crucible was corroded throughout.

208
Affinities of magneſia.

The affinities of magneſia, according to Bergman, are as follows :

Oxalic acid,
Phoſphoric,
Sulphuric,
Fluoric,
Sebacic,
Arſenic,
Saccholactic,
Succinic,
Nitric,
Muriatic,
Tartarous,
Citric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus ?
Water.

Sect. III. *Of Barytes.*

209
Diſcovery of barytes.

A very heavy mineral is found in Sweden, Germany, and Britain, which Margraf conſidered as a compound of ſulphuric acid and lime. But Scheele and Gahn analyſed it in 1774, and found that it conſiſted of ſulphuric acid combined with a peculiar ſpecies of earth. This analyſis was ſoon after confirmed and extended by Bergman. The earth was at firſt called *terra-ponderoſa, heavy earth,* on account of the great ſpecific gravity of the ſubſtance from which it was obtained. Morveau called it *barote* (from βαρυς, *heavy*), which Bergman changed into *barytes* ; and this laſt term is now univerſally adopted.

210
Method obtaining it.

Barytes is generally found combined either with ſulphuric or carbonic acid. From the firſt of theſe compounds, which is by far the moſt common, it may be obtained by the following proceſs :

Reduce the mineral to a powder, and mix it with $2\frac{1}{2}$, its weight of carbonat of ſoda (T), previouſly deprived of all its water. Expoſe the mixture to a red heat for an hour and a half, avoiding fuſion, and a double decompoſition takes place ; the ſulphuric acid unites with the ſoda, while the carbonic acid combines with the barytes. Waſh it in a ſufficient quantity of water to diſſolve the compound of ſulphuric acid and ſoda, the carbonat of barytes, which is almoſt inſoluble, remains behind. Left it ſhould be mixed with ſome other earths, which is generally the caſe, boil it for three hours in ten times its weight of diſtilled vinegar, the ſpecific gravity of which is 1,033 ; by which the barytes will be diſſolved, and likewiſe the lime and magneſia, if there happen to be any ; but every other earth (U) remains untouched. Pour off the ſolution, and add to it ſulphuric acid as long as any precipitate is formed. This precipitate conſiſts of the whole barytes and the lime (if there be any) combined with ſulphuric acid. Waſh it in 50 times its weight of water, and all the lime will be diſſolved. There will now remain nothing but barytes combined with ſulphuric acid, which may be decompoſed as before by carbonat of ſoda §. The carbonic acid may then be ſeparated by applying a very violent heat † ; or, what is better, nitric acid may be poured upon it, which will ſeparate the carbonic acid and combine with the barytes ; and then the nitric acid may be driven off by a moderate heat §.

§ *Afswe*, *Ann. de Chim.* iii
† *Hope, Edin. Tr* iv. 36.
§ *Fourcr* and *Vau*lin, *Ann Chim.* x 276.

Barytes thus obtained is a light ſpongy, porous, body, which may be very eaſily reduced to powder. It has a harſh and more cauſtic taſte than lime ; and when taken into the ſtomach, proves a moſt violent poiſon. It has no perceptible ſmell.

211
Its prop ties.

Its ſpecific gravity has not yet been aſcertained.

It imbibes water with a hiſſing noiſe, but, according to Dr Hope, without ſwelling or ſplitting as lime does ‖. However, when expoſed to the air, as Fourcroy and Vauquelin inform us, it effloreſces, cracks, burſts, ſwells up, heats and becomes white, by abſorbing moiſture §.

Cold water diſſolves about $\frac{1}{25}$ part of its weight of barytes, and boiling water more than half its weight. As the water cools, the barytes is depoſited in cryſtals, the ſhape of which varies according to the rapidity with which they have been formed. When moſt regular, they are flat hexagonal priſms, having two broad ſides, with two intervening narrow ones, and terminated at each end by a four-ſided pyramid, which in ſome inſtances conſtitutes the larger part of the cryſtal. When formed ſlowly, they are diſtinct and large ; but when the

‖ *Edin. Transf.* i
§ *Ann. Chim.* ib and *Ni*ſon's *Jo* i. 535.

(T) Soda is an alkali ; which ſhall be afterwards deſcribed. Carbonat of ſoda is ſoda combined with carbonic acid, the common ſtate in which it is obtained ; potaſs might alſo be uſed.

(U) Except ſtrontites, which Pelletier has detected in this mineral.

the water is ſaturated with barytes, they are depoſited rapidly, and are generally more ſlender and delicate. Then, too, they are attached to one another in ſuch a manner as to aſſume a beautiful foliacious appearance, not unlike the leaf of a fern ¶.

Theſe cryſtals are tranſparent and colourleſs, and appear to be compoſed of about 53 parts of water and 47 of barytes. When expoſed to the heat of boiling water, they undergo the *watery fuſion*, or, which is the ſame thing, they melt without loſing any of the water which they contain. A ſtronger heat makes the water fly off. When expoſed to the air, they attract carbonic acid, and crumble into duſt. They are ſoluble in 17½ parts of water at the temperature of 60°; but boiling water diſſolves any quantity whatever: the reaſon of which is evident; at that temperature their own water of cryſtallization is ſufficient to keep them in ſolution§.

Water ſaturated with barytes is called *barytic water*. It has the property of converting vegetable blues to a green.

When barytes is expoſed to the blow-pipe on a piece of charcoal, it fuſes, bubbles up, and runs into globules, which quickly penetrate the charcoal‡. This is probably in conſequence of containing water; for Lavoiſier found barytes not affected by the ſtrongeſt heat which he could produce.

212 lphuret barytes.

Barytes combines readily with ſulphur. The eaſieſt way of forming ſulphuret of barytes is to mix eight parts of ſulphuret of barytes with one part of pounded charcoal, and to apply a ſtrong heat. The charcoal combines with the oxygen of the ſulphuric acid, and the compound flies off in the form of carbonic acid gas. There remains behind ſulphur combined with barytes. Sulphuret of barytes is ſoluble in water: It is of a yellow colour. It is capable of cryſtallizing; and then aſſumes a yellowiſh white colour||.

The phoſphuret of barytes has not been examined.

No mixture of barytes and lime, nor of barytes and magneſia is fuſible in the ſtrongeſt heat which it has been poſſible to apply§.

213 s affini- es.

The affinities of barytes, according to Bergman, are as follows:

Sulphuric acid,
Oxalic,
Succinic,
Fluoric,
Phoſphoric,
Saccholactic,
Suberic(v)?
Nitric,
Muriatic,
Sebacic,
Citric,
Tartarous,
Arſenic,
Fluoric,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruſſic,
Sulphur,
Phoſphorus,
Water,
Fixed oils.

SECT. IV. *Of Strontites.*

214 Diſcovery of ſtrontites.

ABOUT the year 1787, a mineral was brought to Edinburgh by a dealer in foſſils, from the lead mine of Strontian in Argyleſhire, where it is found imbedded in the ore, mixed with ſeveral other ſubſtances. It is ſometimes tranſparent and colourleſs, but generally has a tinge of yellow or green. Its hardneſs is 5. Its ſpecific gravity varies from 3,4 to 3,726. Its texture is generally fibrous; and ſometimes it is found cryſtallized in ſlender priſmatic columns of various lengths‡.

This mineral was generally conſidered as a carbonat of barytes; but Dr Crawford having obſerved ſome differences between its ſolution in muriatic acid and that of barytes, mentioned in his treatiſe on *muriat of barytes*, publiſhed in 1790, that it probably contained a new earth, and ſent a ſpecimen to Mr Kirwan that he might examine its properties. Dr Hope had alſo ſuſpected that its baſis differed from barytes; and accordingly he made a ſet of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1792. Theſe experiments fully proved that it contained a peculiar earth. Mr Kirwan likewiſe analyſed the ſtrontian mineral, and drew preciſely the ſame concluſions. It has been analyſed alſo by Mr Klaproth of Berlin, and Mr Pelletier of Paris. It conſiſts of carbonic acid combined with a peculiar earth, to which Dr Hope gave the name of *ſtrontites*. This appellation we ſhall adopt.

The carbonic acid may be ſeparated by a heat of 140° Wedgewood, and then the ſtrontites remains behind*.

Strontites has been found in Argyleſhire in Scotland, near Briſtol in England, and in Pennſylvania†. It has been found alſo in France and in Sicily.

215 Its properties.

It is of a white colour. It has a pungent acrid taſte. When pounded in a mortar, the powder that riſes is offenſive to the noſtrils and lungs‡. It is not poiſonous||.

One hundred and ſixty-two parts of water, at the temperature of 60°, diſſolve nearly one part of it. The ſolution is clear and tranſparent, and converts vegetable blues to a green. Hot water diſſolves it in much larger quantities; and as it cools the ſtrontites is depoſited in colourleſs tranſparent cryſtals. Theſe are in the form of thin quadrangular plates, generally parallelograms, the largeſt of which ſeldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener conſiſt of two facets, meeting together and forming an angle like the roof of a houſe. Theſe cryſtals generally adhere to each other in ſuch a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they aſſume a cubic form. They contain about 68 parts in 100 of water. They are ſoluble in 51,4 parts of water, at the temperature of 60°. Boiling water diſſolves nearly half its weight of them. When expoſed to the air, they loſe their water, attract carbonic acid, and fall into powder*.

When ſtrontites is thrown into water, it attracts it with

¶ *Hope, ibid.*

§ *Id.*

‡ *Fourcroy* d *Vauque-*, *ibid.*

|| *Fourcroy.*

§ *Lavoiſier*, *ad. Par.* ·82.

‡ *Hope, Edin. Tranſ.* iv. 44.

* *Kirwan's Miner.* i. 332.

† *Klaproth*, ii. ſect. 39.

‡ *Hope, ibid.*

|| *Pelletier.*

* *Hope, ibid.*

(v) Suberic acid decompoſes muriat and nitrat of barytes. *Jameſon's Mineral. of Shetland and Arran.*

Silica.

Proportions.	Heat.	Effect.
80 Silica 20 Barytes	155° Wedg.	A white brittle maſs.
75 Silica 20 Barytes	150	A brittle hard maſs, ſemi-tranſparent at the edges.
66 Silica 33 Barytes	150	Melted into a hard ſomewhat porous porcelain maſs.
50 Silica 50 Barytes	148	A hard maſs not melted.
20 Silica 80 Barytes	148	The edges were melted into a pale greeniſh matter between a porcelain and enamel.
25 Silica 75 Barytes	150	Melted into a ſomewhat porous porcelain maſs.
33 Silica 66 Barytes	150	Melted into a yellowiſh and partly greeniſh white porous porcelain.

4. The effect of heat on mixtures of ſtrontites and ſilica is not known.

222
d lime,
gneſia,
l ſilica.

5. It follows from the experiments of Achard, that equal parts of lime, magneſia, and ſilica, may be melted into a greeniſh coloured glaſs, hard enough to ſtrike fire with ſteel; that when the magneſia exceeds either of the other two, the mixture will not melt; that when the ſilica exceeds, the mixture ſeldom melts, only indeed with him in the following proportions; three ſilica, two lime, one magneſia, which formed a porcelain; and that when the lime exceeds, the mixture is generally fuſible.*

* Mem.
l. ibid.
l Jour. de
yſ. xxiv.

223
finities
ſilica.

The affinities of ſilica are as follows:

Fluoric acid,
Fixed alkali.

SECT. VI. *Of Alumina.*

224
thod of
aining
mina.

DISSOLVE alum in hot water, and add to the ſolution potaſs as long as any precipitate is formed. Decant off the fluid part, and waſh the precipitate in a ſufficient quantity of water, and then allow it to dry. The ſubſtance thus obtained is called *alumina*. Its properties were firſt aſcertained with accuracy by Margraf.

225
l proper-
s.

Alumina thus obtained is a very white ſpongy powder, without any ſmell or taſte.

Its ſpecific gravity is 2,00†. It is ſcarcely ſoluble in water, but may be diffuſed through it with great facility.

† Kirwan's
Miner. i. 9.

Alumina.

With a ſmall quantity of water it forms a very tough ductile paſte, and does not readily mix with more.

In its uſual ſtate of dryneſs it is capable of abſorbing 2½ times its weight of water, without ſuffering any to drop out. It retains this water more obſtinately than any of the earths hitherto deſcribed. In a freezing cold it contracts more, and parts with more of its water than any other earth; a circumſtance which is of ſome importance in agriculture.*

* Ibid.

Alumina has never yet been obtained in a cryſtallized form. It has no effect whatever on vegetable colours.

The moſt intenſe heat does not fuſe it, but it has the ſingular property of diminiſhing in bulk in proportion to the intenſity of the fire to which it is expoſed. It becomes at the ſame time exceedingly hard: Mr Lavoiſier rendered it capable of cutting glaſs; and Mr Boyle had long before done the ſame thing.*

* Shaw's Boyle, iii. 422.

226
Wedgewood's
thermometer.

Wedgewood took advantage of this property of alumina, and by means of it conſtructed an inſtrument for meaſuring high degrees of heat. It conſiſts of pieces of clay of a determinate ſize, and an apparatus for meaſuring their bulk with accuracy: One of theſe pieces is put into the fire, and the temperature is eſtimated by the contraction of the piece. For a more complete deſcription of this important inſtrument, we refer to the article THERMOMETER in the *Encycl.*

Alumina is hardly ſuſceptible of combining with ſulphur or phoſphorus; but from the experiments of La Grange, it appears to have an affinity for carbon‡.

‡ Nicholſon's Jour. ii. 101.

227
Effect of
heat on
mixtures of
lime and
alumina;

1. The effect of heat on various mixtures of lime and alumina will appear from the following table§.

§ Kirwan, i. 56.

Proportions.	Heat.	Effect.
75 Lime 25 Alumina	150° Wedg.	Not melted.
66 Lime 33 Alumina	150	Remained a powder.
33 Lime 66 Alumina	(x)	Melted.
25 Lime 75 Alumina	(x)	Melted.
20 Lime 80 Alumina	(x)	Melted.

228
Magneſia
and alumina;

2. Magneſia and alumina have no action whatever on each other, even when expoſed to a heat of 150° Wedgewood.*

* Ibid. i. 57.

229
Barytes and
alumina;

3. The effect of heat on different mixtures of barytes and alumina will appear from the following experiments of Mr Kirwan†.

† Ibid.

(x) Theſe three experiments were made by Ehrman: The heat was produced by directing a ſtream of oxygen gas on burning charcoal, and is the moſt intenſe which it has been hitherto poſſible to produce.

Proportions.	Heat.	Effect.
80 Alumina 20 Barytes	150° Wedg.	Scarcely hardened.
75 Alumina 25 Barytes	156	No ſign of fuſion, a looſe powder.
66 Alumina 33 Barytes	152	As the former.
50 Alumina 50 Barytes	150	As the former.
20 Alumina 80 Barytes	148	Somewhat harder, but no ſign of fuſion.
25 Alumina 75 Barytes	150	Harder, but no ſign of fuſion.

4. Nothing is known concerning the effect of heat on mixtures of ſtrontites and alumina.

230 Alumina and ſilica;

5. Equal parts of alumina and ſilica harden in the temperature of 160° Wedgewood, but do not fuſe. Achard found them infuſible in all proportions in a heat probably little inferior to 150° Wedgewood. Mixtures of theſe two earths in various proportions form *clays*, but theſe are ſeldom uncontaminated with ſome other ingredients.

231 Lime, magneſia, and alumina:

6. From the experiments of Achard, it appears that no mixture of lime, magneſia, and alumina, in which the lime predominates, is vitrifiable, except they be nearly in the proportions of three lime, two magneſia, one alumina; that no mixture in which magneſia predominates will melt in a heat below 166°; that mixtures in which the alumina exceeds are generally fuſible, as will appear from the following table†:

3 Alumina 2 Lime 1 Magneſia	A porcelain.
3 Alumina 1 Lime 2 Magneſia	A porcelain.
3 Alumina 1 Lime 3 Magneſia	Porous porcelain.
3 Alumina 2 Lime 3 Magneſia	Porous porcelain.
3 Alumina 2 Lime 2 Magneſia	Porcelain.

232 Lime, ſilica, and alumina;

7. From the ſame experiments, and thoſe of Kirwan, we learn, that, in mixtures of lime, ſilica, and alumina, when the lime exceeds, the mixture is generally fuſible either into a glaſs or a porcelain, according to the proportions. The only infuſible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina

That if the ſilica exceeds, the mixture is frequently fuſible into an enamel or porcelain, and perhaps a glaſs; and that when the alumina exceeds, a porcelain may often be attained, but not a glaſs‡.

233 Magneſi ſilica, an alumina

8. As to mixtures of magneſia, ſilica, and alumina, when the magneſia exceeds, no fuſion takes place at 150°. When the ſilica exceeds, a porcelain may often be attained; and three parts ſilica, two magneſia, and one alumina, formed a glaſs. When the alumina exceeds, nothing more than a porcelain can be produced *

234 And Li magneſi ſilica, an alumina.

9. Achard found that equal parts of lime, magneſia, ſilica, and alumina, melted into a glaſs. They fuſed alſo in various other proportions, eſpecially when the ſilica predominated.

235 Affinitie alumina.

The affinities of alumina are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Oxalic,
Arſenic,
Fluoric,
Sebacic,
Tartarous,
Succinic,
Saccholactic,
Citric,
Phoſphoric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Pruſſic.

SECT. VII. *Of Jargonia.*

236 Diſcover of jarg

AMONG the precious ſtones which come from the iſland of Ceylon, there is one called *jargon*, which is poſſeſſed of the following properties.

Its colour is various, grey, greeniſh white, yellowiſh, reddiſh brown, and violet. It is often cryſtallized, either in right angular quadrangular priſms ſurmounted with pyramids, or octahedrals conſiſting of double quadrangular pyramids. It has generally a good deal of luſtre, at leaſt internally. It is moſtly ſemitranſparent. Its hardneſs is from 10 to 16: Its ſpecific gravity from 4,416 to 4,7.*

It loſes ſcarcely any of its weight in a melting heat; for Klaproth found that 300 grains, after remaining in it for an hour and a half, were only one-fourth of a grain lighter than at firſt†. Neither was it attacked either by muriatic or ſulphuric acid, even when aſſiſted by heat. At laſt, by calcining it with a large quantity of ſoda, he diſſolved it in muriatic acid, and found that 100 parts of it contained 31,5 of ſilica, five of a mixture of nickel and iron, and 68 of an earth poſſeſſed of peculiar properties. This earth has been called *jargonia*.

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* *Kirwan's Min.* i. 58.

† *Ibid.* i. 72.

‡ *Ibid.* i.

* *Ibid.* i.

* *Ibid.* i. 333.

† *Jour. d Phyſ.* 36. 18c.

237 proper- s. Jargonia has a ſtrong reſemblance to alumina. It is of a white colour. Its ſpecific gravity probably exceeds 4,000.

It differs from alumina in the compounds which it forms with other bodies, in being inſoluble in a boiling ſolution of pure potaſs or ſoda, and in being infuſible by heat when mixed with theſe ſubſtances in a ſtate of dryneſs‡. *Kirwan's ineral. p. 14.*

No more of its properties are yet known.

Sect. VIII. *Of Adamanta.*

238 ſcovery adaman- There is a ſtone found in China and in the Eaſt Indies near Bombay, which from its hardneſs has been called *adamantine ſpar*. Mr Greville firſt received ſome ſpecimens of it, and made it known to ſeveral French and Engliſh naturaliſts.

The variety which comes from China is cryſtallized in hexagonal priſms. It is of a grey colour. The entire pieces are opaque, but thin plates of it are tranſparent. It is ſo hard, that it not only cuts glaſs as eaſily as the diamond, but even ſcratches rock cryſtal and many other very hard ſtones. Its ſpecific gravity is 3,710 The variety which comes from Bombay, and which is whiter than the other, is called *corundum**. *Klaprotb, n. de m. i. 3.*

Mr Greville ſent ſome ſpecimens of this ſtone to Mr Klaproth, that he might analyſe it: a taſk which he found very difficult to perform, for the common proceſſes had no effect upon it. At laſt he ſucceeded by fuſing it 12 times in a ſilver crucible with 15 parts of ſoda, and expoſing it each time for five hours to the ſtrongeſt heat which the crucible could endure. After each fuſion he ſoftened the maſs with boiling water, precipitating by acids the earth which the ſoda had diſſolved. He digeſted alſo different times the undecompoſed part in boiling acids. By this proceſs he decompoſed it, and found that it was compoſed of two parts of alumina, and one of a peculiar earth which has been called *adamanta*.

239 proper- s. This earth he at firſt took for ſilica; but it differs from it in not being infuſible when mixed with potaſs or ſoda. Its ſpecific gravity probably exceeds 3,00†. Nothing more is known concerning its properties. *Kirwan's ineral. 17.*

240 lucina. A new earth has lately been diſcovered by Mr Vauquelin in the beryl, to which he has given the name of *glucina*. His account of its properties we have not hitherto been able to procure: we muſt therefore reſerve our deſcription of it till we come in the order of the alphabet to the word Glucina.

241 idneia. Theſe are all the ſimple earths hitherto diſcovered; for *Sidneia*(y), which was announced by Mr Wedgewood as a peculiar earth, has lately been proved by Mr Hatchet* to be merely a mixture of ſeveral earths which have been long known. *Phil. anſ. 98.*

242 marks the rths. The firſt four earths have a great many common properties: they tinge vegetable blues green, they have a ſtrong affinity for carbonic acid, and combine readily with all acids. They have ſometimes been called *alkaline earths*.

There is a ſtrong reſemblance between ſilica and adamanta, and between alumina and jargonia.

None of the earths have been hitherto decompounded, nor has the ſmalleſt proof ever been brought that they are compounds. We muſt therefore, in the preſent ſtate of chemiſtry, conſider them as ſimple bodies. Many attempts, indeed, have been made to ſhew that there was but one earth in nature, and that all others were derived from it. The earth generally made choice of as the ſimpleſt was ſilica(z). But none of theſe attempts, notwithſtanding the ingenuity of ſeveral of the authors, has been attended with the ſmalleſt ſhadow of ſucceſs.

We have mentioned formerly that it was almoſt the univerſal opinion of chemiſts that metals were compoſed of ſome of the earths united to phlogiſton; but of late an attempt has been made to prove that all the earths are metallic oxyds, and that they can actually be reduced to the ſtate of metals.

Baron had long ago ſuſpected that alumina had ſomewhat of a metallic nature; and Bergman had been induced by its great weight, and ſeveral other appearances, to conjecture that barytes was a metallic oxyd: But the firſt chemiſt who ventured to hint that all earths might be metallic oxyds was Mr Lavoiſier*. About the year 1790, ſoon after the publication of Mr Lavoiſier's book, Mr Tondi and Profeſſor Ruprecht, both of Schemnitz, announced that they had obtained from barytes, by the application of a ſtrong heat, a metal of the colour of iron, and attracted by the magnet, which they called *borbonium*; from magneſia another, which they called *auſtrum*; a third from lime, alſo called *auſtrum*; and a fourth from alumina, which they denominated *apulum*. Their method of proceeding was to apply a violent heat to the earths, which were furrounded with charcoal in a Heſſian crucible, and covered with calcined bones in powder. ** Chemiſtry, p. 217. Engliſh tranſl.*

But their experiments were ſoon after repeated by Klraproth, Savoreſi, and Tihauſki; and theſe accurate chemiſts ſoon proved, that the pretended metals were all of them *phoſphurets of iron*. The iron, by the violence of the heat had been extracted from the crucible, and the phoſphorus from the bones. The earths therefore muſt ſtill continue a diſtinct claſs of bodies: and, as Klaproth has obſerved, their properties are ſo exceedingly different from thoſe of metallic oxyds, that the ſuppoſition of their being compoſed of the ſame ingredients is contrary to every fact, and to every analogy with which we are acquainted.

Chap. V. *Of* Caloric.

Nothing is more familiar to us than *heat*; to attempt to define it therefore would be unneceſſary. When we ſay that *a perſon feels heat*, that *a ſtone is hot*, the expreſſions cauſe no difficulty; every one underſtands them perfectly: yet in each of theſe propoſitions the word *heat* has a diſtinct meaning. In the one it ſignifies the *ſenſation* of heat: in the other, the *cauſe* of that ſenſation. This ambiguity, though of little conſequence in common life, leads unavoidably in philoſophical diſcuſſions to confuſion and perplexity. It was to prevent this that the French chemiſts made choice of the word *caloric* to ſignify the *cauſe of heat.* When I put my hand on a hot ſtone, I experience a certain ſenſation, which I call the *ſenſation of heat*; the cauſe of this ſenſation is *caloric.*

(y) This ſubſtance was contained in a mineral brought from Sidney Cove in New-Holland. Wedgewood's analyſis was publiſhed in 1790. Klaproth afterwards analyſed it without finding the new earth which it had been ſuppoſed to contain. But doubts were entertained concerning the identity of the minerals examined by theſe two philoſophers. Theſe doubts have been removed by Mr Hatchet.

(z) Mr Sage, however, pitched upon lime.

243
Whether caloric be a ſubſtance.

Concerning the nature of caloric, there are two opinions which have divided philoſophers ever ſince they turned their attention to the ſubject. Some ſuppoſe that caloric, like gravity, is merely a property of matter, and that it conſiſts, ſome how or other, in a peculiar vibration of its particles; others, on the contrary, think that it is a diſtinct ſubſtance. Each of theſe opinions has been ſupported by the greateſt philoſophers; and the obſcurity of the ſubject is ſuch that both ſides have been able to produce exceedingly plauſible and forcible arguments (13). The recent diſcoveries, however, in this branch of chemiſtry, have rendered the latter opinion much more probable than the former. Indeed we do not ſee how it is poſſible to account for many of the phenomena of nature, unleſs caloric be conſidered as a ſubſtance, as we truſt ſhall appear from the inveſtigation into which we are about to enter. We mean, then, with the generality of modern chemiſts, to take it for granted, that caloric is a ſubſtance, without pretending to be able to demonſtrate the truth of our opinion, but merely becauſe we conſider it as infinitely more plauſible than the other. If the receiver of an air-pump, while it contains a thermometer, be ſuddenly exhauſted of air, the thermometer ſinks ſeveral degrees, and then gradually riſes again to its former height. Now if heat be owing to vibration, how comes it that the ſmall quantity of matter remaining in the receiver is firſt inſufficient, and afterwards ſufficient to maintain the temperature? Is it not more probable that part of the caloric was carried off with the air, and that it gradually returned through the glaſs, which it is capable of pervading, though with difficulty*. When air is let into an exhauſted receiver, the thermometer, as Lambert firſt obſerved, riſes ſeveral degrees. Is not this owing to an additional quantity of caloric introduced by the air? The thermometer then ſinks ſlowly. Is not this becauſe the ſuperabundant caloric gradually pervades the glaſs and flies off? Taking it for granted then, that caloric is a ſubſtance, we proceed to examine its properties.

* See P
tet ſur le
Feu, ch.

244
Caloric e
pands bo
dies.

1. When bodies become hot, or which is the ſame thing, when caloric enters into them, they expand in every direction; and this expanſion is proportional to the accumulation of caloric. The firſt and moſt obvious property of caloric then is the power of expanding bodies. It does not, however, expand all ſubſtances equally, and we are ſtill ignorant of the law which it follows. All that can be done therefore is to collect facts till this law be diſcovered. A number of theſe may be ſeen in the following table:

TABLE *of the Expanſion of various Bodies at different Temperatures.*

* *Blagden.*
† *Newton.*

Temperature.	Water*.	Mercury.	Linſeed Oil†.	Alcohol*.	Temperature.	Water*.	Mercury.	Linſeed Oil†.	Alcohol*.
30°	—	—	—	100000	100	100908	100711,8	—	104162
32	—	100000,0	100000	—	105	—	100762,7		
35	100000	100030,0	—	100267	110	—	100813,6		
40	99997	100081,0	—	100539	120	101404	100915,4		
45	100005	100131,9	—	101818	130	—	101017,2		
50	100023	100182,8	—	101105	140	—	101119,0		
55	100053	100253,7	—	101401	150	102017	101220,8		
60	100091	100304,6	—	101688	160	—	101322,6		
65	100141	100355,5	—	101984	167	102753	—		
70	100197	100406,4	—	102281	170	—	101424,4		
75	100261	100457,3	—	102583	180	—	101526,2		
80	100332	100508,2	—	102890	190	103617	101628,0		
85	100411	100559,1	—	103202	200	—	101729,8		
90	100694	100610,0	—	103517	212	104577	101835,0	107250	
95	100790	100660,9	102560	103840	408	—	—	115160	

* *Blagde*
† *Newto*

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(13) How can the ſupporters of the doctrine of heat being but a vibration of the particles of bodies, reconcile their hypotheſis with the well eſtabliſhed fact of a hot body communicating its heat to the ſurrounding bodies when ſuſpended in a Torricellian vacuum? Will it be ſufficient for them to ſay, that it is never perfectly free from air, and that the ſmalleſt portion is ſufficient to communicate this vibration?

Kirwan. De Luc.

§ *Du Vernois, Encycl. Method.* art. *Air.*

TABLE *of the Expanſion of various Bodies at different Temperatures continued.*

Temperature.	Sulph. acid.*	Nitric acid.*	Glaſs.†	Air.	Oxygen gas.§	Azotic gas.§	Hydrogen gas.§	Nitrous gas.§	Carb. acid gas.§	Ammoniacal gas.§
32°	—	—	100000	100000	100000	100000	100000	100000	100000	100000
40	—	—	—	101790						
45	—	100005	—	—						
50	100149	100149	—	104140						
55	100263	101074	100006	—						
60	100382	101389	—	106560						
65	100615	101767	—	—						
70	100751	102096	—	108950						
75	—	—	100014	—						
77	—	—	—	—	104520	103400	108390	106520	111050	127910
80	—	—	—	111300						
90	—	—	—	113590						
100	—	—	100023	—						
110	—	—	—	117580						
122	—	—	100033	—	124830	121860	122830	117630	130660	184870
130	—	—	—	121870						
150	—	—	100044	126030						
167	—	—	100056	—	190180	176640	137420‡	144370	173850	358780
170	—	—	—	130090						
190	—	—	100069	133970						
212	—	—	100083	134890	547670‡	694120	139120‡	160290‡	200940‡	680090‡ (A)

† *Smeaton, Phil. Tranſ.* xlviii. 612.

TABLE *of the Expanſion of Metals from* 32° *to* 212°.†

Temperature.	Antimony.	Steel.	Iron.	Caſt-Iron.	Biſmuth.	Copper.	Caſt Braſs.	Braſs Wire.
32°	120000	120000	120000	120000	120000	120000	120000	120000
212	120130	120147	120151		120167	120204	120225	120232
White heat		123428*	121500*	122571*				

* *Rinman.*

	Tin.	Lead.	Zinc.	Hammered Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Braſs 2 Zinc 1	Pewter.	Copper 3 Tin (B) 1
32°	120000	120000	120000	120000	120000	120000	120000	120000	120000
212	120298	120344	120355	120373	120323	120301	120247	120274	120218

From

(A) This mark ‡ implies, that, owing to ſome inaccuracy in making the experiments, the numbers to which it is attached are not to be depended on.

(B) The metal whoſe expanſion is here given was an alloy compoſed of three parts of copper and one of tin. The figures in ſome of the preceding columns are to be underſtood in the ſame manner. Thus in the laſt column but two, the metal conſiſted of two parts of braſs alloyed with one of zinc.

245 Exception. From this table, it appears that the gaſes are more expanded by caloric than fluids, and fluids more than ſolids; and that the expanſion of all bodies hitherto examined, mercury alone excepted, goes on in an increaſing ſeries. To the expanding power of caloric there is one ſingular exception: From 30° to 40° Fahrenheit, *water*, inſtead of being expanded, ſuffers a remarkable contraction, as is evident from the following table of its bulk for every degree between 30° and 40.

	Bulk.
30°	100074
31	100070
32	100066
33	100063
34	100060
35	100058
36	100056
37	100055
38	100054
39	100054
40	100054.*

* *Blagden.*

From 40° it expands like other ſubſtances on being heated (B).

246 Thermometer. The expanſion of bodies by caloric has furniſhed us with an inſtrument for meaſuring the various degrees of it in different ſubſtances, we mean the thermometer; and as mercury is the only fluid which expands equably, it is obviouſly the only proper one for thermometers (14). The thermometer uniformly uſed in this article is that of Fahrenheit, except when ſome other is particularly mentioned.

247 No body without caloric. 2. By means of the thermometer, we learn that there is no body which does not contain caloric, becauſe there is none ſo cold that it cannot be made colder: and cooling a body is nothing elſe but abſtracting a part of the caloric which it contains.

248 Equilibrium of caloric. 3. Caloric cannot be confined in any body while thoſe in its neighbourhood are colder, but continues to ruſh out till every thing is reduced to the ſame temperature. This does not proceed from the attraction of the colder bodies, but from the tendency of caloric to exiſt everywhere in an equal degree of tenſion: For when hot bodies are placed in the exhauſted receiver of an air-pump, as we learn from Mr Pictet †, or in the Torricellian vacuum, as Count Rumford has ſhewn us ‡, the caloric leaves them in the ſame manner, tho' more ſlowly, and they are equally reduced to the temperature of the ſurrounding bodies. This property has been called *the equilibrium of caloric*. The only way therefore to confine or accumulate this ſubſtance in a body, is to ſurround it with bodies which are hotter than itſelf.

† *Sur le Feu*, chap. vi.

‡ *Phil. Tranſ.* 1786, Part I.

249 The pa cles of c ric repe each ot 4. The equilibrium of caloric ſeems evidently to prove that its particles repel each other (15). This repulſion will cauſe them when accumulated in any place to fly off in every direction, and to continue to ſeparate till they are oppoſed by caloric in other bodies of the ſame relative denſity with themſelves, which, by repelling them in its turn, compels them to continue where they are. The caloric in bodies therefore is in what has been called by Mr Pictet a ſtate of *tenſion* (C). Its particles are actuated by a force which would make them ſeparate to an indefinite diſtance, were they not confined by the oppoſite force of the caloric which ſurrounds them. The *equilibrium* therefore depends on the balancing of two oppoſite forces; the repulſion between the particles of caloric in the body, which tends to diminiſh the temperature; and the repulſion between the caloric of the body and the ſurrounding caloric, which tends to raiſe the temperature. When the firſt force is greater than the ſecond, as is the caſe when the temperature of a body is higher than that of the ſurrounding bodies, the caloric flies off, and the body becomes colder. When the laſt force is ſtronger than the firſt, as is the caſe when a body is colder than thoſe which are around it, the particles of its caloric are obliged to approach nearer each other, new caloric enters to occupy the ſpace which they had left, and the body becomes hotter. When the two forces are equal, the bodies are ſaid to be of the ſame temperature, and no change takes place.*

* See P tet *ſur le Feu*, ch.

It is the action of theſe oppoſite forces which makes the thermometer a meaſure of temperature. When applied to any body, it continues to riſe or fall till the caloric in it and in the body to which it is applied are of the ſame tenſion, and then it remains ſtationary. The thermometer therefore merely indicates that the temperature of the body to which it is applied is equal to its own. It is obvious that, in order to obtain the real temperature of bodies, the thermometer ſhould be ſo ſmall that the quantity of caloric, which enters or leaves it, may not materially affect the reſult.

This property of caloric ſeems to be the cauſe of the elaſticity of the gaſes, in which, as we ſhall ſhew afterwards,

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(B) There was a curious fact concerning dilatation obſerved by Mr de Luc. A braſs rod which he uſed as a thermometer became in ſummer *habitually* longer; that is to ſay, that after being for ſome time lengthened by heat, it did not contract by the application of cold to its old length, but continued ſomewhat longer. In winter the contrary phenomenon took place. After being contracted for ſome time by cold, it did not return to its old length on the application of heat, but kept ſomewhat ſhorter. A leaden rod ſhewed theſe effects in a greater degree. Glaſs has not this quality. De Luc ſuſpects that this property is inverſely as the elaſticity of bodies. Glaſs is perfectly elaſtic, and lead is leſs elaſtic than braſs.—*Journ. de Phyſ.* xviii. 369.

(14) Mercury does *not* expand regularly even according to the tables juſt given. For every five degrees it there appears that, in moſt inſtances, it expands 50 9, but betwixt 35° and 40° it expands 51. and between 50° and 55° it even expands 70.9, although betwixt 55° and 60° it expands again but 50.9. But this is not the only irregularity the thermometer is liable to. Glaſs is very irregular in its expanſion. The tube and bulb therefore in which the mercury is contained muſt by their irregular expanſions and contractions render this inſtrument inaccurate. T. P. S.

(15) Why need we conſider caloric as a *principle of repulſion* when we can otherwiſe explain all its phenomena. T. P. S.

(C) The phraſe was firſt uſed by Mr Volta.

er quantity, upwards than downwards; owing, doubtleſs, to the repulſive power of the caloric in the earth. The ſmall quantity of air that remained in the tube, may perhaps be ſuppoſed ſufficient to account for the difference, without allowing any ſuch tendency upwards in caloric. But it is evident from the experiments of the Florentine academicians on the ſame ſubject, with tubes full of air, that even when in great abundance, that fluid hardly affected the riſing of the ſuperior thermometer: ſurely then its effect muſt be altogether imperceptible when ſo little of it remained; and in the third and fourth experiments the oiled paper prevented any of the heated air from approaching the thermometer (17).

253
Conducting power of bodies:

5. If we take a bar of iron and a piece of ſtone of equal dimenſions, and putting one end of each into the fire, apply either thermometers or our hands to the other, we ſhall find the extremity of the iron ſenſibly hot long before that of the ſtone. Caloric therefore does not paſs through all bodies with the ſame celerity and eaſe. The power that bodies have to allow it a paſſage through them is called their *conducting power;* thoſe that allow it to paſs with facility, are called *good conductors;* thoſe through which it paſſes with difficulty, are called *bad conductors;* and thoſe which do not allow it to paſs at all, *non-conductors.*

254
Of wood and charcoal;

It is probable that all ſolids conduct heat in ſome degree, at leaſt this is the caſe with every one at preſent known. Wood and charcoal are exceeding bad conductors of caloric (E). Count Rumford informs us, that a piece of green oak plank was employed to ſtir the melted metal of which cannons were founding at Munich, and it was often allowed to remain a conſiderable time in the furnace; yet the caloric had penetrated to ſo inconſiderable a depth, that at the diſtance of $\frac{1}{20}$th of an inch below the ſurface, the wood did not ſeem to have been the leaſt affected by it; the colour remained unchanged, and it did not appear to have loſt even its moiſture*.

* Rumford's Eſſays, ii. 229.

255
Of glaſs;

Glaſs is alſo a very bad conductor; and this is the reaſon that it is ſo apt to crack on being heated or cooled ſuddenly; one part of it receiving or parting with its caloric before the reſt, expands or contracts, and deſtroys the coheſion.

256
Of metals;

Metals are the beſt conductors of caloric of all the ſolids hitherto examined. The conducting powers of all, however, are not equal. Dr Ingenhouſz procured cylinders of ſeveral metals exactly of the ſame ſize, and having coated them with wax, he plunged their ends into hot water, and judged of the conducting power of each by the length of wax-coating melted. From theſe experiments he concluded, that the conducting powers of the metals which he examined were in the following order*:

Silver,
Gold,
Copper, } nearly equal,
Tin,
Platinum,
Iron, } much inferior to the others.
Steel,
Lead,

* Journ. Phyſ. 17 p. 68.

257
Of ſtone and ſolid capable melting.

Next to metals ſtones ſeem to be the beſt conductors; but this property varies conſiderably in different ſtones. Bricks are much worſe conductors than moſt ſtones. All ſolids capable of being melted become non-conductors the moment they are heated to the melting point: the caloric enters them eaſily enough, but it remains in them.

258
All fluid non-conductors caloric.

All fluids hitherto examined are *non conductors of caloric.* They can receive it indeed from other ſubſtances, and they can give it out to other ſubſtances; but one particle can neither receive it nor give it out to another particle. Before a fluid therefore can either be heated or cooled, every particle muſt go individually to the ſubſtance from which it receives or to which it gives out caloric. For this very important diſcovery the world is indebted to Count Rumford. Before the publication of his eſſays it had not even been ſuſpected; ſo far from it, that fluids had been ranked among the beſt conductors of caloric.

259
How thi was diſco vered.

In a ſet of experiments on the communication of heat, he made uſe of thermometers of an uncommon ſize. Having expoſed one of theſe (the bulb of which was near four inches in diameter) filled with alcohol to as great a heat as it could ſupport, he placed it in a window to cool where the ſun happened to be ſhining. Some particles of duſt had by accident been mixed with the alcohol: theſe being illuminated by the ſun, became perfectly viſible, and diſcovered that the whole liquid in the tube of the thermometer was in a moſt rapid motion, running ſwiftly in oppoſite directions upwards and downwards at the ſame time. The *aſcending* current occupied the axis, the *deſcending* current the ſides of the tube. When the ſides of the tube were cooled by means of ice, the velocity of both currents was accelerated. It diminiſhed as the liquid cooled; and when it had acquired the temperature of the room, the motion ceaſed altogether. This experiment was repeated with linſeed oil, and the reſult was preciſely the ſame. Theſe currents were evidently produced by the particles of the liquid going individually to the ſides of the tube, and giving out their caloric. The moment they did ſo, their ſpecific gravity being increaſed, they fell to the bottom, and of courſe puſhed up the warmer part of the fluid, which was thus forced to aſcend along the axis of the tube. Having reached the top of the tube, the particles gave out part of their caloric, became ſpecifically heavier, and tumbled in their turn to the bottom.

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(17) Theſe experiments of Mr Pictet are undoubtedly ingenious, but by no means concluſive. There ſtill remained a conſiderable quantity of air in the tube. This air became rarified juſt in the centre of the tube where the mirror converged the ſun's rays. Hence this air would riſe up to the top of the tube, and part with its extra quantum of heat to the upper thermometer. This air would be replaced from above, and thus a conſtant ſtream of warm air towards the upper thermometer would be produced. Thus might we account for the riſe of the upper thermometer without the aid of a *principle of levity.* That the lower thermometer ſhould riſe but ſlowly is not ſurpriſing when we conſider the experiments of Count Rumford on the conducting powers of air, which, *at leaſt,* prove it to be a *very bad* conductor of caloric. The oiled paper not preventing the thermometer riſing is no proof that it is not this ſtream of warm air which cauſes the upper thermometer to riſe, unleſs it be proved that it is a non-conductor of caloric, and if it were I do not ſee how the caloric is to get through to the thermometer eaſier if it poſſeſſes abſolute *levity* than if it be a gravitating fluid. All, I think, theſe experiments prove is, that the ſpecific gravity of caloric is leſs than that of the imperfect vacuum Mr Pictet made uſe of. T. P. S.

(E) This fact merits the attention of chemiſts. It is obvious, that when metallic oxyds are ſurrounded with charcoal powder, their temperature cannot be raiſed near ſo high as it otherwiſe would be. It is not unlikely that ſome part of the difficulty which has been experienced in attempting to reduce and fuſe ſeveral metallic ſubſtances may have been owing to this cauſe.

As theſe internal motions of fluids can only be diſcovered by mixing with them bodies of the ſame ſpecific gravity with themſelves, and as there is hardly any ſubſtance of the ſame ſpecific gravity with water which is not ſoluble in it, Count Rumford had recourſe to the following ingenious method of aſcertaining whether that fluid alſo followed the ſame law. The ſpecific gravity of water is increaſed conſiderably by diſſolving any ſalt in it; he added, therefore, potaſs to water till its ſpecific gravity was exactly equal to that of amber, a ſubſtance but very little heavier than pure water. A number of ſmall pieces of amber were then mixed with this ſolution, and the whole put into a glaſs globe with a long neck, which, on being heated and expoſed to cool, exhibited exactly the ſame phenomena with the other fluids. A change of temperature, amounting only to a very few degrees, was ſufficient to ſet the currents a-flowing; and a motion might at any time be produced by applying a hot or a cold body to any part of the veſſel. When a hot body was applied, that part of the fluid neareſt it aſcended; but it deſcended on the application of a cold body.

260 ofs of non-ducting ver of er,

If caloric paſs through water only by the internal motion of its particles, as this experiment ſeems to prove, it is evident that every thing which embarraſſes theſe motions muſt retard its tranſmiſſion: and accordingly Count Rumford found this to be the caſe. He took a large linſeed-oil thermometer with a copper bulb and glaſs tube: the bulb was placed exactly in the centre of a braſs cylinder, ſo that there was a void ſpace between them all around 0,25175 of an inch thick. The thermometer was kept in its place by means of four wooden pins projecting from the ſides and bottom of the cylinder, and by the tube of it paſſing through the cork ſtopper of the cylinder. This cylinder was filled with pure water, then held in melting ſnow till the thermometer fell to 32°, and immediately plunged into a veſſel of boiling water. The thermometer roſe from 32° to 200° in 597″. It is obvious that all the caloric which ſerved to raiſe the thermometer muſt have made its way through the water in the cylinder. The experiment was repeated exactly in the ſame manner, but the water in the cylinder, which amounted to 2276 gr. had 192 gr. of ſtarch boiled in it, which rendered it much leſs fluid. The thermometer now took 1109″ to riſe from 32° to 200°. The ſame experiment was again repeated with the ſame quantity of pure water, having 192 gr. of eiderdown mixed with it, which would merely tend to embarraſs the motion of the particles. A quantity of ſtewed apples were alſo in another experiment put into the cylinder. The following tables exhibit the reſult of all theſe experiments.

Time the Caloric was in paſſing into the Thermometer.

Temperature.	Through the Water and Starch	Thro' the Water and Eiderdown.	Through ſtewed Apples	Through pure Water
	Seconds.	Seconds,	Seconds.	Seconds.
Therm. roſe from 32° to 200° in	1109	949	1096½	597
Therm. roſe 80°, *viz* from 80° to 160°, in	341	269	335	172

Time the Caloric was in paſſing out of the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through ſtewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
Therm. fell from 200° to 40° in	1548	1541	1749½	1032
Therm. fell 80°, *viz.* from 160° to 80°, in	468	460	520	277

Now, neither the ſtarch nor the eiderdown could produce any alteration in the water except impeding its internal motions: conſequently whatever impedes theſe motions diminiſhes the conducting power of water. But this could not happen unleſs every individual particle actually went from the cylinder to the thermometer.

Only one proof more was wanting to remove every doubt; and this proof alſo Count Rumford has given us. If water be a non-conductor, it is evident that no caloric can paſs downwards when the heat is applied to the ſurface; for as the particles of water become ſpecifically lighter by being heated, they cannot ſink to the bottom. Accordingly Count Rumford found, that water might be made actually to boil near the top of a glaſs tube, while that at the bottom was not ſenſibly warmed. Owing to the law already mentioned, indeed, that water, after being cooled down to 40°, expands inſtead of contracting when its temperature is lowered, a maſs of water may be raiſed to 40° by applying the heat to its upper ſurface; becauſe water at 40° is heavier than at any degree below it, and will therefore ſink to the bottom; but its temperature cannot be raiſed any higher. This Count Rumford proved, by ſhewing that water of the temperature of 40°, placed above ice, will melt as much of it in the ſame time as water at any higher temperature whatever, even boiling hot.

Into a cylindrical glaſs jar 4,7 inches in diameter and 13,8 inches high, he put 43,87 cubic inches, or 1 lb. $11\frac{1}{7}$ oz. troy of water, and placing the jar in a freezing mixture compoſed of pounded ice and common ſea ſalt, he froze the water into one compact maſs. The jar was then put into a mixture of pounded ice and pure water, reaching exactly to the top of the ice in it, and ſuffered to remain there four hours, that the ice might come to the temperature of 32°; then boiling water was cautiouſly poured on it, and the jar ſtill allowed to ſtand in the ice and water. He ſoon found that a conſiderable quantity of ice was melted at the very beginning of the experiment, owing to the agitation into which the water was thrown by the act of pouring it into the veſſel. To prevent this as much as poſſible, he covered the ice with a ſmall quantity of ice cold water, upon which he placed a flat ſhallow diſh of light wood $4\frac{1}{2}$ inches in diameter, and about one-fourth of an inch thick at the bottom. This veſſel was perforated by ſeveral hundred very ſmall holes. The hot water was poured into this diſh through a long wooden tube, the bottom of which was ſtopped up, and the water made to iſſue through ſmall holes in the ſide at the lower end. As this diſh always floated on the ſurface of the water, and as the fluid paſſing through it by a number of ſmall holes was not projected with force, it is evident that a conſiderable part of theſe violent motions was prevented. The following is the reſult of three experiments made in this manner.

Number of Experiments.	Time the hot Water was on the Ice.	Temperature of the hot Water one inch below its ſurface.		Quantity of Ice melted.
		At the beginning.	At the end	
	Minutes.			Grains.
1	10	192°	182°	580
2	30	190°	165°	914
3	180	190°	95°	3200

From theſe experiments he determined the quantity of ice melted in the act of pouring the water into the jar, ſuppoſing equal quantities to be melted in equal times. If 3200 grains were melted in 180′, ſubtracting 580, the quantity melted in 10′, there remains 2620 gr. for the quantity melted in 170′, in every ten of which 154 gr. muſt have been melted; for 170 : 10 : : 2620 : 154 nearly. Subtracting 154 from 580, the quantity melted in the firſt ten minutes, there remains 426 gr. for the quantity melted in pouring the water into the jar. From the ſecond experiment it follows, by a ſimilar calculation, that 159 gr. were melted every 10 minutes; which ſhows that the motions produced by pouring in the water had not ceaſed in 30 minutes. It will be nearer the truth, therefore, if we endeavour to diſcover the quantity melted every ten minutes by comparing the ſecond and third experiments. By a ſimilar calculation to the above, it comes out to be 152 gr. The following table exhibits the reſults of ſeveral experiments, made exactly in the ſame manner, but with water at a much lower temperature.

Number of Experiments.	Temper. of the Water in the Jar one inch below its ſurface.		Temper. of the Air.	Time the Water remained on the Ice.	Quantity of Ice melted.
	Before.	After.			
1	41°	40°	41°	10′	203 gr.
2	41	40	41	10	220
3	41	40	41	10	237
4	41	40	41	10	228
5	41	38	41	30	617
6	41	38	41	30	585

From theſe experiments it appears that the quantity of ice melted in 10′ by water at the temperature of 41° was 222 gr. while boiling water melted only 152 gr. in the ſame time. To diſcover whether any of this was melted in the act of pouring in the water; from a mean of the two laſt experiments it appears, that 601 grains were melted in 30′: if from this 222 grains (the mean of the four firſt) be deducted, there will remain 379 grains for the quantity melted in 20′, conſequently $189\frac{1}{2}$ grains is what muſt have been melted in the ordinary courſe of the proceſs; a quantity conſiderably above 152 grains. Therefore water at 41° melts more ice in the ſame time than boiling water. This Count Rumford accounts for by ſuppoſing, that in the hot water the deſcending current from the top of the veſſel, and aſcending one from the ice, meeting one another in that part of the veſſel where the temperature is 40°, retard each others motions, and thus prevent the melting proceſs from going on ſo rapidly as when there is no deſcending current. And he found accordingly, that when the cooling of the water above was retarded by wrapping up the jar in a warm covering, the ice melted faſter; and when the cooling above was accelerated, it melted ſlower. It is evident, that in the one caſe the velocity of the deſcending current was diminiſhed, in the other accelerated.

Thus it has been completely proved, that water is a non-conductor of caloric. But is this the caſe alſo with other liquids?

26
Oil an
mercu

When water was frozen in a glaſs jar by means of a freezing mixture, Count Rumford obſerved, that the ice firſt began to be formed at the ſides, and gradually increaſed in thickneſs; and that the water on the axis of the veſſel, which retained its fluidity longeſt, being compreſſed by the expanſion of the ice, was forced upwards, and when completely frozen formed a pointed projection or nipple, which was ſometimes half an inch higher than the reſt of the ice. Upon ice frozen in this manner, he poured olive oil, previouſly cooled down to 32°, till it ſtood at the height of three inches above the ice. The veſſel was ſurrounded as high as the ice with a mixture of pounded ice and water. A ſolid cylinder of wrought iron, $1\frac{1}{4}$th inch in diameter and 12 inches long, provided with a hollow cylindrical ſheath of thick paper, was heated to the temperature of 210° in boiling water; and being ſuddenly introduced into its ſheath, was ſuſpended from the ceiling of the room, and very gradually let down into the oil, until the middle of the flat ſurface of the hot iron, which was directly above the point of conical projection of the ice, was diſtant from it only $\frac{2}{10}$ths of an inch. The end of the ſheath deſcended $\frac{1}{10}$th of an inch lower than the end of the hot metallic cylinder. Now it is evident, that if olive oil was a conductor, caloric would paſs down through it from the iron and melt the ice. None of the ice, however, was melted; and when mercury was ſubſtituted for oil, the reſult was juſt the ſame;* conſequently it follows, that neither oil nor mercury is a conductor of heat. We may conclude, therefore, with Count Rumford, that this is the caſe with liquids in general.

Rumford, ſſay vii. art ii. hap. I.

262 Air;

Sennebier obſerved ſome time ago, that air was a very bad conductor of caloric, and that it reſiſted every change of temperature very much.* But it was reſerved for Count Rumford to prove, that it conducted it at all only by the internal motions of its particles, or that it was in fact a *non-conductor*, exactly in the ſenſe that liquids are non-conductors.* This he eſtabliſhed by ſhewing, that whatever tended to obſtruct or impede the internal motions of its particles, diminiſhed its conducting power. By mixing with a quantity of air $\frac{1}{50}$th of its bulk of eiderdown, he diminiſhed its conducting power more than one half. The warmth of furs and feathers and ſilk depends on a very ſtrong attraction between them and air, which is therefore confined in their interſtices, and thus the caloric prevented from paſſing out of the body. A *ſingle* metallic cover to a boiler in a ſhort time grew ſo hot that it could not be touched, while another of exactly the ſame form, but *double*, with a quantity of air confined in the middle, ſcarcely felt hot ‡. There can be no doubt that all the gaſes are alſo non-conductors; and Count Rumford has proved the ſame thing of ſteam by the following experiment, which we ſhall relate in his own words †:

Journ. de hyſ. 1788.

Phil. ranſ. 792, art I.

Rumford, ſſay vi.

Ibid. . 61.

263 And ſteam.

" A large globular bottle being provided, of very thin and very tranſparent glaſs, with a narrow neck, and its bottom drawn inward ſo as to form a hollow hemiſphere about 6 inches in diameter; this bottle, which was about 8 inches in diameter externally, being filled with cold water, was placed in a ſhallow diſh, or rather plate, about 10 inches in diameter, with a flat bottom formed of very thin ſheet braſs, and raiſed upon a tripod, and which contained a ſmall quantity (about $\frac{2}{10}$ths of an inch in depth) of water; a ſpirit lamp being then placed under the middle of this plate, in a very few minutes the water in the plate began to boil, and the hollow formed by the bottom of the bottle was filled with clouds of ſteam, which, after circulating in it with ſurpriſing rapidity 4 or 5 minutes, and after forcing out a good deal of air from under the bottle, began gradually to clear up. At the end of 8 or 10 minutes (when, as I ſuppoſed, the air remaining with the ſteam in the hollow cavity formed by the bottom of the bottle had acquired nearly the ſame temperature as that of the ſteam) theſe clouds totally diſappeared; and though the water continued to boil with the utmoſt violence, the contents of this hollow cavity became ſo perfectly inviſible, and ſo little appearance was there of ſteam, that, had it not been for the ſtreams of water which were continually running down its ſides, I ſhould almoſt have been tempted to doubt whether any ſteam was actually generated.

" Upon lifting up for an inſtant one ſide of the bottle, and letting in a ſmaller quantity of cold air, the clouds inſtantly returned, and continued circulating ſeveral minutes with great rapidity, and then gradually diſappeared as before. This experiment was repeated ſeveral times, and always with the ſame reſult; the ſteam always becoming viſible when cold air was mixed with it, and afterwards recovering its tranſparency when, part of this air being expelled, that which remained had acquired the temperature of the ſteam.

" Finding that cold air introduced under the bottle cauſed the ſteam to be partially condenſed, and clouds to be formed, I was deſirous of ſeeing what viſible effects would be produced by introducing a cold ſolid body under the bottle. I imagined that if ſteam was a conductor of heat, ſome part of the heat in the ſteam paſſing out of it into the cold body, clouds would of courſe be formed; but I thought if ſteam was a non-conductor of heat, that is to ſay, if one particle of ſteam could not communicate any part of its heat to its neighbouring particles, in that caſe, as the cold body could only affect the particles of ſteam actually in contact with it, no cloud would appear, and the reſult of the experiment ſhewed that ſteam is in fact a non-conductor of heat; for, notwithſtanding the cold body uſed in this experiment was very large and very cold, being a ſolid lump of ice nearly as large as an hen's egg, placed in the middle of the hollow cavity under the bottle, upon a ſmall tripod or ſtand made of iron wire; yet as ſoon as the clouds which were formed in conſequence of the unavoidable introduction of cold air in lifting up the bottle to introduce the ice, were diſſipated, which ſoon happened, the ſteam became ſo perfectly tranſparent and inviſible, that not the ſmalleſt appearance of cloudineſs was to be ſeen anywhere, not even about the ice, which, as it went on to melt, appeared as clear and as tranſparent as a piece of the fineſt rock cryſtal." Thus, then, it appears, that all elaſtic fluids are non-conductors as well as liquids.

264 Specific caloric of bodies, what.

6. If equal quantities of water and of mercury be placed at the ſame diſtance from a fire, the mercury will become hot much ſooner than the water. After a ſufficient interval, however both of them acquire the ſame temperature. Now caloric flows into all bodies while they continue of a lower temperature than thoſe around them, and it flows with equal rapidity into all bodies of the ſame conducting powers, as is the caſe with theſe two fluids: But if equal quantities of caloric were conſtantly flowing into the mercury and the water, and yet the water took a longer time to become hot than the mercury, it muſt require a greater quantity of caloric to raiſe water to a given temperature than it does to raiſe mercury. Bodies that require a greater quantity of caloric to raiſe them to a particular temperature than other bodies require, are ſaid to have a greater *capacity* for caloric. That the capacity for caloric is different in different bodies, was firſt obſerved by Dr Black.

Dr Irvine afterwards inveſtigated the ſubject, and Dr Crawford publiſhed a great number of experiments on it in his *Treatiſe on Heat.* Profeſſor Wilcke of Stockholm, alſo diſcovered the ſame property of bodies. He called the quantity of caloric neceſſary to raiſe the temperature of ſubſtances a given number of degrees, their *ſpecific caloric*; a term which we ſhall alſo employ, becauſe the phraſe *capacity for caloric* is liable to a great deal of ambiguity, and has introduced confuſion into this ſubject (F). If two ſubſtances of unequal temperatures, as water at 100° and alcohol at 50°, be mixed together, the mixture will be of a temperature different both from that of the water and the alcohol, the water will become colder and the alcohol hotter: the water will give out caloric to the alcohol till both are reduced to the ſame temperature. Now if it requires juſt as much caloric to raiſe alcohol a certain number of degrees as it does to raiſe water the ſame number, that is, if theſe two fluids are of the ſame ſpecific caloric, it is evident that the temperature of the mixture will be juſt 75°; for as ſoon as the water has given out 25° of caloric, the alcohol has acquired 25°, conſequently both will be reduced to the ſame temperature, and will remain ſtationary; but if the ſpecific caloric of the water be greater than that of the alcohol, the temperature of the mixture will be higher than 75°: for 25° of caloric in that caſe would raiſe alcohol more than 25°. If the ſpecific caloric of water be ſo much greater than that of alcohol, that what raiſes water 20° will raiſe alcohol 30°; then the temperature after mixture will be 80°, becauſe, when the water has given out 20°, the alcohol will have riſen 30°, and of courſe both will be of the ſame temperature. On the contrary, if the ſpecific caloric of alcohol were greater than that of water, the temperature of the mixture would be under 75°. If the ſame quantity of caloric that raiſed alcohol 20°, raiſed water 30°, then the temperature of the mixture would be 70°. Thus the ratios of the ſpecific caloric of bodies may be diſcovered by mixing them together at different temperatures (18).

265 Experiments on ſpecific caloric by Wilcke, The firſt ſet of experiments on this ſubject, in point of time, were probably thoſe of Mr Wilcke. They were firſt publiſhed in the Stockholm Tranſactions for 1781, but had been made long before. The manner in which they were conducted is exceedingly ingenious, and they furniſh us with the ſpecific caloric of many of the metals. The metal on which the experiment was to be made was firſt weighed accurately (generally one pound was taken), and then being ſuſpended by a thread, was plunged into a large veſſel of tinplate, filled with boiling water, and kept there till it acquired a certain temperature, which was aſcertained by a thermometer. Into another ſmall box of tinplate exactly as much water at 32° was put as equalled the weight of the metal. Into this veſſel the metal was plunged, and ſuſpended in it ſo as not to touch its ſides or bottom; and the degree of heat, the moment the metal and water were reduced to the ſame temperature, was marked by a very accurate thermometer. He then calculated what the temperature would have been if a quantity of water equal in *weight* to the metal, and of the ſame temperature with it, had been added to the ice-cold water inſtead of the metal.

Let M be a quantity of water at the temperature C, m another quantity at the temperature c, and let their common temperature after mixture be x; according to a rule demonſtrated long ago by Richman, $x = \frac{MC+mc}{M+m}$. In the preſent caſe the quantities of water are equal, therefore M and m are each $=1$; C, the temperature of the ice-cold water $= 32$: therefore $\frac{MC+mc}{M+m} = \frac{32+c}{2}$. Now c is the temperature of the metal. Therefore if 32 be added to the temperature of the metal, and the whole be divided by 2, the quotient will expreſs the temperature of the mixture, if an equal weight of water with the metal, and of the ſame temperature with it, had been added to the ice-cold water inſtead of the metal.

He then calculated what the temperature of the mixture would have been if, inſtead of the metal, a quantity of water of the ſame temperature with it, and equal to the metal in *bulk*, had been added to the ice-cold water. As the weights of the ice-cold water and the metal are equal, their volumes are inverſely as their ſpecific gravities. Therefore the volume of ice-cold water is to a quantity of hot water equal in volume to the metal, as the ſpecific gravity of the metal to that of the water. Let M = volume of cold water, m = volume of hot water, g = ſpecific gravity of the metal, 1 = ſpecific gravity of water; then $m : M :: 1 : g$; hence

$m =$

(F) The term *ſpecific caloric* has been uſed in a different ſenſe by Seguin. He uſed it for the *whole caloric* which a body contains.

(18) This appears to me to be by no means a juſt method of judging of the ſpecific caloric of bodies even when it can be practiſed. The very foundation is error. It is conſidering the properties of the conſtituent principles by that of the compound. This never can be done with certainty and in this particular caſe facts prove it to be peculiarly erroneous. According to the principles of this *teſt*, if any two ſubſtances were mixed together at the *ſame* temperature the compound would be of the ſame temperature as each of them would have a ſufficiency of caloric to maintain them juſt at that temperature. Let us combine ſulphuric acid and water, and water and muriat of ammoniac, at equal temperatures, and obſerve what takes place. In the firſt caſe the temperature is much encreaſed and in the other decreaſed. Why do theſe changes take place? Becauſe the compound is not of a mean *ſpecific caloric* to the conſtituent principles. No inference from its temperature therefore can be drawn as to the *ſpecific caloric* of thoſe principles. T. P. S.

$m = \frac{M}{g}$ =(M being made = 1) $\frac{1}{g}$. Subſtituting this value of m in the formula, $\frac{MC + mc}{M + m} = x$, in which M = 1 and C = 32, x will be $= \frac{32\,g + c}{g + 1}$. Therefore if the ſpecific gravity of the metal be multiplied by 32, and the temperature of the metal be added, and the ſum be divided by the ſpecific gravity of the metal + 1, the quotient will expreſs the temperature to which the ice-cold water would be raiſed by adding to it a volume of water equal to that of the metal, and of the ſame temperature with it.

He then calculated how much water at the temperature of the metal it would take to raiſe the ice-cold water the ſame number of degrees which the metal had raiſed it. Let the temperature to which the metal had raiſed the ice-cold water be = N, if in the formula $\frac{MC+mc}{M+m} = x$, x be made = N, M = 1, C = 32, m will be $= \frac{N - 32}{c - N}$. Therefore if from the temperature to which the ice-cold water was raiſed by the metal 32 be ſubtracted, and if from the temperature of the metal be ſubtracted the temperature to which it raiſed the water and the firſt remainder be divided by the laſt, the quotient will expreſs the quantity of water of the temperature of the metal which would have raiſed the ice-cold water the ſame number of degrees that the metal did.

Now $\frac{N-32}{c-N}$ expreſſes the ſpecific caloric of the metal, that of water being = 1. For (neglecting the ſmall difference occaſioned by the difference of temperature) the weight and volume of the ice-cold water are to the weight and volume of the hot water as 1 to $\frac{N-32}{c-N}$, and the number of particles of water in each are in the ſame proportion. But the metal is equal in weight to the ice-cold water; it muſt therefore contain as many particles of matter; therefore the quantity of matter in the metal muſt be to that in the hot water, as 1 to $\frac{N-32}{c-N}$. But they give out the ſame quantity of caloric; which, being divided equally among their particles, gives to each particle a quantity of caloric inverſely as the bulks of the metal and water; that is, the ſpecific caloric of the water is to that of the metal as 1 to $\frac{N-32}{c-N}$ (G).

We ſhall now give a ſpecimen or two of his experiments, and the calculations founded on them, as above deſcribed.

GOLD. *Specific Gravity* 19,040.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temper. to which it would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temperature to which it would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fractions $\frac{N-32}{c-N}=\frac{1}{\frac{c-N}{N-32}}$, the numerator being 1.
1	163,4°	38,3°	97,7°	38,555°	19,857
2	144,5	37,4	88,25	37,58	19,833
3	127,4	36,5	79,7	36,68	20,500
4	118,4	36,05	75,2	36,15	20,333
5	103,1	35,6	65,75	35,42	18,750
6	95	34,45	63,5	35,06	19,000

Mean 19,712

LEAD. *Specific Gravity* 11,456.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raiſed the water at 32°.	Temperature to which the water would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temperature to which the water would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{1}{\frac{c-N}{N-32}}$
1	186,8	38,3	109,4	44,425	23,571
2	181,40	37,85	106,7	43,473	24,538
3	165,2	37,4	98,6	42,692	23,666
4	163,4	37,4	97,7	42,548	23,333
5	136,4	36,5	84,2	40,344	22,200
6	131	36,05	81,5	39,947	24,700
7	126,5	36,05	79,25	39,585	22,333
8	107,6	35,15	69,8	38,339	23,000
9	94,1	34,7	63,05	36,985	22,000

Mean 23,515

It

(G) We have altered all theſe formulas to make them correſpond with Fahrenheit's thermometer. They are a good deal ſimpler when the experiments are made with Celſius's thermometer as Mr Wilcke did. In it the freezing point is zero; and conſequently inſtead of 32 in the formula, 0 is always ſubſtituted.

It is needleſs to add, that the laſt column marks the denominator of the ſpecific caloric of the metal; the numerator being always 1, and the ſpecific caloric of water being 1. Thus the ſpecific caloric of gold is $\frac{1}{19,712}$. In exactly the ſame manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke aſcertain the ſpecific caloric of a number of other bodies. He aſcertained at the ſame time, that the ſpecific caloric of a body did not vary with the temperature, but continued always the ſame. This will appear evident from the experiments on gold and lead above exhibited.

266 Crawford, Next, in point of time, and not inferior in ingenious contrivances to enſure accuracy, were the experiments of Dr Crawford, made by mixing together bodies of different temperatures. Theſe were publiſhed in his *Treatiſe on Heat*.

267 Lavoiſier and La Place, Several experiments on the ſpecific caloric of bodies were made alſo by Lavoiſier and De la Place, which, from the well-known accuracy of theſe philoſophers, cannot but be very valuable.

Their method was exceedingly ſimple and ingenious; it was firſt ſuggeſted by De la Place. An inſtrument was contrived, to which Lavoiſier gave the name of *calorimeter*. It conſiſts of three circular veſſels nearly inſcribed into each other, ſo as to form three different appartments, one within the other. Theſe three we ſhall call the *interior*, *middle*, and *external cavities*. The interior cavity *ffff* (ſee ſection of the inſtrument fig. 4.), into which the ſubſtances ſubmitted to experiment are put, is compoſed of a grating or cage of iron wire, ſupported by ſeveral iron bars. Its opening or mouth LM is covered by the lid HG, which is compoſed of the ſame materials. The middle cavity *bbbb* is filled with ice. This ice is ſupported by the grate *mm*, and under the grate is placed a ſieve. The external cavity *aaaa* is alſo filled with ice. We have mentioned already, that no caloric can paſs through ice. It can enter ice, indeed, but it remains in it, and is employed in melting it. The quantity of ice melted, then, is a meaſure of the caloric which has entered into the ice. The exterior and middle cavities being filled with ice, all the water is allowed to drain away, and the temperature of the interior cavity to come down to 32°. Then the ſubſtance, the ſpecific caloric of which is to be aſcertained, is heated a certain number of degrees, ſuppoſe to 212°, and then put into the interior cavity incloſed in a thin veſſel. As it cools, it melts the ice in the middle cavity. In proportion as it melts, the water runs through the grate and ſieve, and falls through the conical funnel *c c d* and the tube *x y* into a veſſel placed below to receive it. The external cavity is filled with ice, in order to prevent the external air from approaching the ice in the middle cavity and melting part of it. The water produced from it is carried off through the pipe ST. The external air ought never to be below 32°, nor above 41°. In the firſt caſe, the ice in the middle cavity might be cooled too low; in the laſt, a current of air flows through the machine and carries off ſome of the caloric. By putting various ſubſtances at the ſame temperature into this machine, and obſerving how much ice each of them melted in cooling down to 32°, it was eaſy to aſcertain the ſpecific caloric of each. Thus, if water, in cooling from 212 to 32, melted one pound of ice, and mercury ,029 of a pound; the ſpecific caloric of water was one, and that of mercury ,029. This appears by far the ſimpleſt method of making experiments on this ſubject; and muſt alſo be the moſt accurate, provided we can be certain that all the melted ſnow flows into the receiver. But from an experiment of Mr Wedgewood, one would be apt to conclude that this does not happen. He found that the melted ice, ſo far from flowing out, actually *froze* again, and choaked up the paſſage.

26 And I wan. A table of the ſpecific caloric of various bodies was likewiſe drawn up by Mr Kirwan, and publiſhed by Magellan in his Treatiſe on Heat.

26 Reſul theſe ments From all theſe ſources we have drawn up the following table, which exhibits at one view the ſpecific caloric of thoſe bodies on which experiments have hitherto been made.

We have added to it a column, expreſſing the ſpecific caloric of equal bulks of the ſame bodies; which ſeems to be a more accurate way of conſidering this ſubject, and indeed the only way in which the phraſe *capacity for caloric* is intelligible. This column was formed by multiplying the ſpecific caloric of equal weights of the various ſubſtances into their reſpective ſpecific gravities.

TABLE

270 Latent caloric, or

271 Caloric of fluidity.

7. If a quantity of ice, at a low temperature, ſuppoſe at 20°, be ſuſpended in a warm room, it will become gradually leſs cold, as may be diſcovered by means of a thermometer, till it reaches the temperature of 32°; but there it ſtops. The ice, however, diſſolves ſlowly; and at the end of ſeveral hours, when it is all juſt melted, the thermometer ſtill ſtands at 32°. After this it begins to riſe, and ſoon reaches the temperature of the room. Here the ice continues for ſeveral hours colder than the air around it. Caloric muſt then be continually flowing into it; yet it does not become hotter; it is changed, however, into water. Ice therefore is converted into water by a quantity of caloric uniting with it. This caloric has been called *latent caloric*, becauſe its preſence is not indicated by the thermometer. It might, perhaps with more propriety, as Profeſſor Pictet obſerves†, be called *caloric of fluidity*; for there are other caſes in which caloric exiſts in bodies without raiſing their temperature. This very important diſcovery was made by Dr Black as early as 1757, and ſeems to have led the way to all the ſubſequent diſcoveries in this part of chemiſtry, which have almoſt completely changed the appearance of the ſcience: for the diſcovery that caloric may exiſt in bodies while the thermometer cannot indicate its preſence, is one of the ſtrongeſt links in the chain of facts by which the nature of combuſtion was aſcertained.

† *Sur le Feu*, ch. I.

The caloric which unites with ice, and renders it fluid, appears again during the act of *freezing*. If a quantity of water be carried into a room where the temperature is below the freezing point, ſuppoſe at 20° it cools gradually down to 32°; but it becomes no colder till it is all frozen, which takes up ſome time. The moment it is all converted into ice, it begins again to cool, and ſoon reaches the temperature of the room. In this caſe the water is ſurrounded by a colder atmoſphere; it muſt therefore be giving out caloric conſtantly; yet it does not become colder till it is all frozen, that is to ſay, till it has loſt all its *caloric of fluidity*.

Dr Black proved, by a very accurate experiment, that the quantity of *caloric of fluidity* is ſufficient to raiſe the ſame quantity of water 140°.

All ſolids become fluid by abſorbing a quantity of caloric. Landriani proved that this is the caſe with ſulphur, alum, nitre, and ſeveral of the metals‡ and it has been found to be the caſe with every ſubſtance hitherto examined. Fluidity, therefore, is owing to a union between the ſolid, and a certain quantity of caloric.

‡ *Jour. de Phyſ.* xxvi.

The late Dr Irvine of Glaſgow advanced a theory on this ſubject different from that of Dr Black. The ſpecific caloric of water being greater than that of ice, it requires a greater quantity of caloric to raiſe it to a given temperature than it does to raiſe ice. The caloric does not therefore become *latent*; it only ſeems to do ſo from the greater ſpecific caloric of water. This theory was zealouſly adopted by Dr Crawford. Dr Black obſerved very juſtly that it did not account for the production of fluidity at all. The ſpecific caloric of water is indeed greater than that of ice; but how is the ice converted into water? This is an objection which the advocates for Dr Irvine's, or Dr Crawford's theory (as it has been improperly called) will not eaſily anſwer. Let us now examine whether this theory accounts for the apparent loſs of caloric. It follows from Mr Kirwan's experiments, that the ſpecific caloric of water is to that of ice as 10 to 9 (1). Dr Black proved that as much caloric entered the ice as would have raiſed it, had it been water, 140°. Let us ſuppoſe that it would only have raiſed the ice 140°; in that caſe the melted ice ought to have been of the temperature of 158°, for 10 : 9 : : 140 : 126; but it was only 32°: Therefore 126° of caloric have diſappeared, and cannot be accounted for by the change of ſpecific caloric, nor can the accuracy of Dr Black's experiment be ſuſpected: it has been repeated in every part of the world, and varied in every poſſible way. We cannot doubt, therefore, that caloric unites with ſubſtances, and cauſes them to become fluid, or that *there is in fact a caloric of fluidity different from ſpecific caloric.*

272 Caloric of evaporation.

Water alſo is converted into *ſteam* by uniting with caloric. Dr Black put an iron veſſel, containing four ounces of water at the temperature of 53°, upon a caſt-iron table which was red hot. The water roſe to the boiling point in three minutes; but it did not afterwards become any hotter. It evaporated, however, in 18 minutes; and the ſteam was preciſely at the temperature of 212°. During the firſt three minutes, it received 159° of caloric, and as much muſt have been entering it during every three minutes while the evaporation continued, as the temperature was always much lower than that of the table. This caloric, inſtead of raiſing the temperature of the water, was employed in converting it into ſteam. There is alſo, therefore, a quantity of latent caloric in ſteam. It might, as Mr Pictet obſerves, be called, with propriety, *caloric of evaporation*. This caloric appears again if the ſteam be condenſed. If it be made to paſs, for inſtance, through a pipe ſurrounded with cold water, it is condenſed in the pipe, and drops out from it in the form of water. The caloric of the ſteam enters into the water around the pipe, and the quantity of it in degrees may be diſcovered by the number of degrees which it raiſes that water. By an experiment of this kind, it was proved, that the caloric of evaporation would be ſufficient to heat water red hot, were it employed only in raiſing its temperature, inſtead of converting it into ſteam. It is therefore at leaſt equal to 800°. Mr Watt ſhewed afterwards that it was 920°.

Even ſpontaneous evaporation, as Dr Black firſt obſerved, is owing to the ſame cauſe. And this explains why bodies cool when water is evaporated from their ſurface; a fact which has long been known, and which has been employed in warm countries to diminiſh the temperature of liquids, and even to convert them into ice (K). That water is evaporated by uniting with caloric, and not by ſolution in air, has been proved very completely by De Luc in his Treatiſe on Meteorology.

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(1) We do not know how this was aſcertained: Not by mixing water and ice ſurely; becauſe that would be taking for granted the thing to be proved; becauſe it would give a very different reſult, and what is ſtill worſe, the ſpecific caloric in that caſe would differ according to the temperature, and the quantity of water. To give an inſtance: Mr Gadolin concludes, from 180 experiments made by mixing hot water and ice, that the ſpecific caloric of ice is to that of water only as 1 to 2*; and had he varied the quantities and the temperatures, he might have obtained ſeveral other ratios.

* *Ann. de Chim.* xi. 27.

The evaporation of alcohol, ether, and every other ſubſtance on which experiments have been made, has been found owing to the ſame cauſe. Bodies, therefore, are converted into vapour by uniting with caloric.

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8. If caloric, as has been ſhewn, exiſts in bodies at the loweſt temperature which we are able to procure, and if it exiſts in them while the thermometer cannot diſcover its preſence—is there any method of aſcertaining its abſolute quantity in bodies? At what degree would a thermometer ſtand (ſuppoſing the thermometer capable of meaſuring ſo low) were the body to which it is applied totally deprived of caloric? or what degree of the thermometer correſponds to the real zero?

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The firſt perſon (as far as we know), at leaſt ſince men began to think accurately on the ſubject, who conceived the poſſibility of determining this queſtion, was Dr Irvine of Glaſgow. He invented a theorem in order to aſcertain the real zero, which has, we know not for what reaſon, been aſcribed by ſeveral writers to Mr Kirwan. He took it for granted, and the fact is proved by all the experiments hitherto made) that the ſpecific caloric of bodies continued the ſame in every degree of temperature, as long as they remained in the ſame ſtate, that is to ſay, as long as they continued either ſolid or fluid, or in a ſtate of vapour: but that the ſpecific caloric of the ſame body while ſolid was leſs than while fluid, and leſs while fluid than while in a ſtate of vapour. He took it for granted too, that the 140 degrees of caloric which entered ice during its ſolution without raiſing its temperature, entered merely in conſequence of the increaſed ſpecific caloric of the water, and that they were exactly proportional to this increaſed ſpecific caloric. He took it for granted, likewiſe, that the ſpecific caloric of bodies was proportional to their *abſolute caloric*, or to all the caloric which exiſted in each.

On theſe data he reaſoned in the following manner: Let A be a body in a ſtate of fluidity; B the ſame body in a ſtate of ſolidity. If the ſpecific caloric of A and of B be known, and if it be known how many degrees the

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(K) Galen informs us, that the ancient Egyptians were accuſtomed to put water previouſly boiled into earthen jars, and expoſe them all night on the upper part of their houſes to the air. Before ſunriſe theſe veſſels were put into the ground moiſtened on the outſide with water, and then ſurrounded with freſh plants; by which means the water was preſerved cool during the whole day. *Comment. in lib.* vi. *Hippoc. de morbis vulgar.* 4. 10. p. 396.

By a ſimilar proceſs, water, in the Eaſt Indies, is converted into ice.

The following ſingular paſſage, which has been pointed out to us by the ingenious Dr Barclay, lecturer on anatomy in Edinburgh, furniſhes a ſtriking proof that the ancients were led, by a very different method of reaſoning, to deduce from their philoſophical theory of the four elements, concluſions concerning the nature of heat, not very different from thoſe of the moderns.

" Sic enim res ſe habet, ut omnia, quæ alantur, et quæ creſcant, contineant in ſe vim caloris; ſine qua neque ali poſſent nec creſcere. Nam omne, quod eſt calidum et igneum, cietur et agitur motu ſuo: quod autem alitur et creſcit, motu quodam utitur certo et æquabili; qui quandiu remanet in nobis, tamdiu ſenſus et vita remanet: refrigerato autem et extincto calore, occidimus ipſi et extinguimur. Quod quidem Cleanthes his etiam argumentis docet, quanta vis inſit caloris in omni corpore: negat enim ullum eſſe cibum tam gravem, quin is nocte et die concoquatur; cujus etiam in reliquiis ineſt calor his quas natura reſpuerit. Jam vero venæ et arteriæ micare non deſinunt, quaſi quodam igneo motu; animadverſumque ſæpe eſt, cùm cor animantis alicujus evolſum ita mobiliter palpitaret, ut imitaretur igneam celeritatem. Omne igitur quod vivit, ſive animal ſive terra editum, id vivit propter incluſum in eo calorem. Ex quo intellegi debet, eam caloris naturam, vim habere in ſe vitalem per omnem mundum pertinentem. Atquè id faciliùs cernemus, toto genere hoc igneo, quod tranat omnia, ſubtiliùs explicato. Omnes igitur partes mundi (tangam autem maxumas) calore fultæ ſuſtinentur. Quod primùm in terrena natura perſpici poteſt. Nam et lapidum conflictu atque tritu elici ignem videmus; et recenti foſſione

——*terram fumare calentem;*

atque etiam ex puteis jugibus aquam calidam trahi, et id maxùme fieri temporibus hibernis quòd magna vis caloris, terræ contineatur cavernis; eaque hieme ſit denſior; ob eamque cauſſam, calorem incitum in terris contineat arctiùs.

" Longa eſt oratio, multæque rationes, quibus doceri poſſit omnia, quæ terra concipiat, ſemina, quæque ipſa ex ſe generata ſtirpibus infixa contineat, ea temperatione caloris et oriri et augeſcere. Atque aquæ etiam admixtum eſſe calorem primùm ipſe liquor, tum aquæ declarat effuſio: quæ neque conglaciaret frigoribus, neque nive pruinaque concreſceret, niſi eadem ſe admixto calore liquefacta et dilapſa diffunderet. Itaque et aquilonibus reliquiſque frigoribus dureſcit humor: et idem viciſſim mollitur tepefactus et tabeſcit calore. Atque etiam maria agitata ventis ita tepeſcunt, ut intellegi facilè poſſit, in tantis illis humoribus eſſe incluſum calorem. Nec enim ille externus et adventicius habendus eſt tepor, ſed ex intimis maris partibus agitatione excitatus: quod noſtris quoque corporibus contingit, cùm motu atque exercitatione recaleſcunt. Ipſe verò aër, qui natura eſt maxumè frigidus, minime eſt expers caloris. Ille verò et multo quidem calore admixtus eſt: ipſe enim oritur ex reſpiratione aquarum: earum enim quaſi vapor quidam aër habendus eſt. Is autem exiſtit motu ejus caloris, qui aquis continetur. Quam ſimilitudinem cernere poſſumus in his aquis, quæ efferveſcunt ſubditis ignibus. Jam verò reliqua quarta pars mundi, ea et ipſa totá natura fervida eſt, et ceteris naturis omnibus ſalutarem inpertit et vitalem calorem. Ex quo concluditur, cùm omnes mundi partes ſuſtineantur calore, mundum etiam ipſum ſimili parique natura in tanta diuturnitate ſervari: eoque magis quòd intellegi debet calidum illud atque igneum ita in omni fuſum eſſe natura, ut in eo inſit procreandi vis et cauſſa gignendi, à quo et animantia omnia, et ea quorum ſtirpes terra continentur, et naſci ſit neceſſe et augeſcere. *Cicero de natura Deorum*, lib ii. c. 9, *et* 10.

the caloric, diſengaged during the change of B into A, would raiſe the temperature of A, it may be found by an eaſy proceſs how many degrees all the caloric contained in B would raiſe the temperature of A; and the ſum of theſe two numbers will repreſent in degrees the whole quantity of caloric in A: for the quantity of caloric in A muſt be juſt equal to the caloric in B, together with what entered into it in paſſing from the ſtate of B to that of A. Let the ſpecific caloric of A be 6, that of B 1; and let the quantity of caloric diſengaged during the change of A into B be ſufficient to raiſe the temperature of A 500°. If the ſpecific caloric be proportional to the abſolute caloric, it muſt contain exactly 6 times as much caloric as B. The 500° which entered into A when it changed its ſtate, muſt be juſt 5 times as great as all the caloric of B; becauſe when added to the caloric of B, it formed the caloric in A, which is juſt 6 times as great as the caloric in B. Therefore to diſcover the caloric in B, we have only to divide 500 by 5, or, which is the ſame thing, to ſtate this proportion 6—1 : 500 : : 1 : 100. The caloric in B, therefore, in this caſe is juſt as much as would raiſe the temperature of A 100°. Therefore, if to 100°, the caloric of B, be added 500°, = caloric diſengaged in the paſſage of A to B, this will give 600°, = to all the caloric in A. Therefore, in all caſes, the difference between the numbers expreſſing the ſpecific caloric of the ſolid and fluid, is to the number expreſſing the ſpecific caloric of the ſolid, as the quantity of caloric diſengaged during the paſſage of the fluid into a ſolid is to the quantity of caloric in the fluid.

Dr Crawford embraced this theorem; and concluded, from a number of experiments made on purpoſe to aſcertain the fact, that the real zero was 1268° below 0, or 1300° below the freezing point.

275
Examined,

This ſubject deſerves to be conſidered with attention. If this theorem in fact furniſhes us with the real zero, it is one of the moſt important diſcoveries which has ever been made in chemiſtry; but if it proceeds on erroneous principles, it will only involve us in endleſs mazes of error and abſurdity.

In the firſt place, if the real zero has any meaning at all, it muſt ſignify the degree to which the thermometer (ſuppoſing it could be uſed) would ſink on being applied to a body which contained no heat. It muſt therefore be a fixed point; and were the theorem which we are examining well founded, experiments upon every different ſubſtance, if conducted with accuracy, would lead to the ſame reſult. Let us ſee whether this be the caſe.

From Dr Crawford's experiments, it follows, as we have ſeen, that the real zero is 1268° below 0.

Mr Kirwan, from comparing the ſpecific caloric of water and ice, fixed the real zero at 1048° below 0.

From the experiments of Lavoiſier and La Place on a mixture of water and quicklime, in the proportion of 9 to 16, it follows, that the real zero is 2736° below 0.

From their experiments on a mixture of 4 parts of ſulphuric acid and 3 parts of water, it follows, that the real zero is 5803,4° below 0.

Their experiments on a mixture of 4 parts of ſulphuric acid and 5 of water, place it at 2073,3° below 0.

Their experiments on $9\frac{1}{3}$ parts of nitric acid and 1 of lime, place it at $\frac{1889}{-0,01783}$ below 32°*.

Theſe reſults differ from one another ſo enormouſly, and the laſt of them, which makes the real zero a negative quantity, is ſo abſurd, that they are alone ſufficient to convince us that the data on which they are founded are not true. Should it be ſaid that their difference is not owing to any defect in the theorem, but to inaccuracies in making the experiments—we anſwer, that the theorem itſelf is founded on ſimilar experiments; and if experiments of this nature, even in the hands of the moſt accurate chemiſts, cannot be freed from ſuch enormous errors, how can we depend on any conſequences deduced from them? and where, then, is our evidence for the truth of the theorem?

But, farther, there is no proof whatever that the ſpecific caloric of bodies is proportional to their abſolute caloric. The ſpecific caloric of iron is greater than that of water, or even azotic gas; yet ſurely it is very improbable that iron contains more abſolute caloric than either of theſe ſubſtances.

If the ſpecific caloric of bodies has any meaning at all, it can only be, that the ſame quantity of caloric raiſes the temperature of one body a greater number of degrees than it does another. When we ſay that the ſpecific caloric of A is = 6, and that of B = 1, what do we mean, unleſs that the quantity of caloric which raiſes B 6° raiſes A only 1°, or that what raiſes B 60° or 600°, raiſes A only 10° or 100°? When we ſay that the ſpecific caloric of water is 10, and that of ice 9, do we not mean, that the quantity of caloric which raiſes the ice 10° or 100°, raiſes water only 9° or 90°? Yet during the change of ice into water, 140° of caloric enter it without raiſing its temperature; a quantity greater than what can be accounted for by the difference of ſpecific caloric by 126°. The quantity that diſappears, therefore, is *not* proportional to the difference of ſpecific caloric; and therefore any theory which depends on that ſuppoſition cannot be well founded. When water is converted into ſteam, 800° of caloric diſappear; yet the ſpecific caloric of ſteam is to that of water, according to Dr Crawford's own experiments, only as 155 to 100: ſo that no leſs than 283° diſappear, which cannot be accounted for according to this theory.

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Dr Irvine's theorem, therefore, is inſufficient for aſcertaining the real zero; and hitherto no method has been diſcovered which can ſolve this problem (19).

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Caloric e
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9. If there be no body without caloric, if it exiſts in different quantities in different bodies, even when their temperatures are the ſame, and while the thermometer cannot indicate its preſence—in what ſtate does it exiſt in them? We cannot ſurely ſuppoſe that it is contained by them juſt as water is contained by a veſſel of wood or metal, or that they are filled with it in the ſame manner that a hollow globe of tin-plate perforated with holes is filled with water when it is plunged into a quantity of that liquid; or that bodies are filled with caloric merely becauſe they are immerſed in an ocean of caloric. Were that the caſe, the ſpecific and abſolute caloric of bodies would always be proportional; and they

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* See S
guin, A.
de Chim.

(19) He attempted to compute the real zero as much without data, as a mathematician who ſhould attempt to compute the length of a line by knowing that part of it was an inch long, without knowing the proportion of that part to the whole. T. P. S.

278 l ſtate of cmical cbina- t.

they would of neceſſity be inverſely as the ſpecific gravity of the reſpective bodies; becauſe the leſs the ſpecific gravity, the more room would be left for the particles of caloric. But this is by no means the caſe: the ſpecific gravity of iron, for inſtance, is greater than that of tin, yet the ſpecific caloric of iron is more than double that of tin: the ſpecific gravity of oxygen gas is greater than that of common air, yet the ſpecific caloric of the firſt of theſe ſubſtances is more than three times as great as that of the other. There muſt be ſomething, therefore, in bodies themſelves quite different from, and unconnected with the vacuities between their particles, which diſpoſes ſome to admit more caloric than others. And what can that be but a diſpoſition in different bodies to unite with a greater or a ſmaller quantity of caloric, and to retain it with more or leſs firmneſs according to their *affinity* for it? Dr Black pointed out, long ago, by diſcovering latent heat, that caloric unites with bodies; and this ſeems to be the only real key for unfolding the actions of this extraordinary ſubſtance. If caloric be matter, can it be deſtitute of that property which all other matter poſſeſſes, we mean attraction? And if it poſſeſſes attraction, muſt it not combine with thoſe bodies that attract it juſt as other bodies combine with each other? Muſt there not be formed a chemical union between caloric and other ſubſtances, which can only be broken by chemical means, by preſenting a third body which has a greater affinity either for the caloric or the body to which it is united, than they have for each other?

279 ved to the caſe iquids, ours,

That it unites chemically with ſome bodies, at leaſt, cannot be doubted; as we have ſhewn already, that whenever a ſolid is converted into a liquid, a quantity of caloric enters, and remains in it; and that both the ſolid and the caloric loſe their characteriſtic properties. This is preciſely what takes place in every chemical union. All liquids, therefore, conſiſt of ſolids combined with caloric. We have ſeen, too, that liquids are converted into vapours by the very ſame proceſs. There are therefore, at leaſt, two very large claſſes of bodies liquids and vapours, in which we are certain that caloric exiſts in a ſtate of chemical combination.

280 d gaſes;

There is another claſs of bodies which reſemble vapours in almoſt all their properties: theſe are the gaſes. Like them, they are inviſible and elaſtic, and capable of indefinite expanſion. Is it not probable, then, that the gaſes alſo, as well as the vapours, owe their properties to caloric? that they alſo conſiſt of their reſpective baſes combined with that ſubtile ſubſtance? This probability has been reduced to certainty by an experiment of Lavoiſier. By adding two tubes to the calorimeter formerly deſcribed, he contrived to make known quantities of air to paſs through the interior cavity, and to ſupport combuſtion. He found, that when a pound of oxygen gas was made to combine in this manner with phoſphorus, as much caloric was diſengaged as melted $87\frac{1}{2}$ pounds of ice*. Now every pound of ice abſorbs as much caloric in the act of melting as is ſufficient to raiſe a pound of water 140°. Therefore the whole caloric diſengaged was ſufficient to raiſe a pound of water 12250°. All this could not have come from the phoſphorus, becauſe it had been converted into a liquid, and muſt therefore have abſorbed inſtead of parted with caloric, and becauſe the quantity of caloric diſengaged in all caſes of combuſtion is proportional, not to the combuſtible, but to the oxygen abſorbed. Oxygen gas, then, is compoſed of oxygen and caloric: and if this be the caſe with one gas, why not with all?

We may conclude, therefore, that the gaſes, as well as liquids and vapours, owe their form to the caloric which they contain. The only difference between them and vapours is, that the latter return to their liquid ſtate by the mere action of cold; whereas moſt of the gaſes reſiſt the loweſt temperature which it has been poſſible to apply. It was natural to expect, that if caloric combined chemically with bodies, its affinity would be different for different ſubſtances, and that its affinity for ſome bodies would be ſo great that it would not leave them to combine with any other. It was natural to expect this, becauſe it is the caſe with every other ſubſtance with which we are acquainted. The difference, then, between the gaſes and vapours is not ſurpriſing. The affinity of the former for caloric is not only much greater than that of the latter, but much greater than that of any other ſubſtances.

281 And to be the cauſe of their gaſeous form.

It is owing to this ſtrong affinity between oxygen, hydrogen, and azot and caloric, that they cannot be obtained except in a gaſeous form: and we ſhall deſcribe ſeveral other ſubſtances afterwards exactly in the ſame circumſtances. Had we any ſubſtance poſſeſſed of a greater affinity for caloric than they have, we ſhould be able, by preſenting it, to deprive them of their gaſeous form. Doubtleſs there is a difference in the affinity between theſe bodies themſelves and caloric; but as all of them are already ſaturated, this difference cannot be diſcovered. If we could obtain them uncombined with caloric, that is to ſay, in a concrete ſtate, it would be eaſy to aſcertain this point. Suppoſe, for inſtance, that hydrogen had the ſtrongeſt affinity for caloric, and that we poſſeſſed it in a concrete ſtate—it would be eaſy, by preſenting it to the other gaſes, to deprive their baſes of the caloric with which they are united, and thus to obtain them alſo uncombined with any other ſubſtance.

282 Why caloric appears during combuſtion,

But though we are acquainted with no ſubſtance that has a greater affinity for caloric than the baſes of the gaſes, there are many ſubſtances which have a greater affinity for theſe baſes than caloric has. When any ſuch ſubſtance is preſented, the baſe combines with it, and the caloric is left at liberty. Thus, when phoſphorus is preſented to oxygen gas, the phoſphorus and oxygen unite together, and the caloric flies off. We are now, therefore, able to anſwer one of the queſtions propoſed at the end of the ſecond chapter. Whence comes the caloric which appears during combuſtion? It is ſeparated from the oxygen, which leaves it in order to enter into a new combination.

283 And during many chemical combinations.

The caloric alſo, which ſometimes appears when two bodies combine together, is ſet at liberty exactly in the ſame manner. When ſulphuric acid and water, for inſtance, are mixed together, a very conſiderable heat is produced; a good deal of caloric, therefore, becomes ſenſible. In this caſe, the water combines with the acid, and at the ſame time lets go the caloric with which it was formerly combined, and becomes denſer. In the ſame manner, to give another inſtance, when water is poured upon quicklime, a very great quantity of caloric becomes manifeſt. The water in this caſe combines with the quicklime, and aſſumes a concrete form, and of courſe lets go the caloric with which it was previouſly united.

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[*] avoiſier, I. ch. 9.

Caloric.

284
Why certain mixtures produce cold.

10. It is no uncommon thing in nature to obſerve two bodies, after combining together, manifeſting a much ſtronger affinity for a third body than either of them had while ſeparate. Thus, ſilver has no perceptible affinity for ſulphuric acid, neither has oxygen: but unite them together, and they combine with that acid very readily. A great many inſtances of the ſame kind might be produced. Were there ſubſtances, then, which, after combining together, have a greater affinity for caloric than any of them had while ſeparate, this ought not to ſurpriſe us, becauſe the ſame phenomenon is often obſerved in other bodies. Now this is actually the caſe with regard to caloric. Mix together, for inſtance, common ſalt and ſnow, the mixture inſtantly becomes liquid, and ſo cold, that it ſinks the thermometer down to zero. In this caſe, the ſnow and ſalt united have a much ſtronger affinity for caloric than either of them had while ſeparate; they attract it therefore from other bodies with which they happen to be in contact, till they have obtained a doſe ſufficient for their ſaturation; and this ſaturation they manifeſt by becoming liquid. It is for this reaſon that all ſalts produce cold during their ſolution in water, when the freezing point of the ſolution formed is below that of water. All ſuch ſolutions have a ſtrong affinity for caloric; they therefore attract it till they are ſaturated, which appears by their becoming fluid. A number of experiments have been lately made in order to procure artificial cold by means of ſuch combinations. The moſt complete ſet of experiments of that nature with which we are acquainted, is thoſe of Mr Walker, publiſhed in the Philoſophical Tranſactions for 1795. We ſhall preſent the reſult of his experiments in the following table:

TABLE of Freezing Mixtures.

Mixtures.		Thermometer ſinks.
Muriat of ammonia	5 parts.	From 50° to 10°.
Nitre -	5	
Water - -	16	
Muriat of ammonia	5	From 50 to 4.
Nitre -	5	
Sulphat of ſoda	8	
Water -	16	
Nitrat of ammonia	1	From 50 to 4.
Water -	1	
Nitrat of ammonia	1	From 50 to 7.
Carbonat of ſoda	1	
Water -	1	
Sulphat of ſoda	3	From 50 to 3.
Diluted nitric acid	2	
Sulphat of ſoda	6	From 50 to 10.
Muriat of ammonia	4	
Nitre -	2	
Diluted nitric acid	4	
Sulphat of ſoda	6	From 50 to 14.
Nitrat of ammonia	5	
Diluted nitric acid	4	
Phoſphat of ſoda	9	From 50 to 12.
Diluted nitric acid	4	
Phoſphat of ſoda	9 parts.	From 50° to 21°.
Nitrat of ammonia	6	
Diluted nitric acid	4	
Sulphat of ſoda	8	From 50 to 0.
Muriatic acid	5	
Sulphat of ſoda	5	From 50 to 3.
Diluted ſulphuric acid	4	
Snow	1	From 32 to 0.
Common ſalt	1	
Snow or pounded ice	2	From 0 to —5.
Common ſalt	1	
Snow or pounded ice	1	From —5 to —18.
Common ſalt -	5	
Muriat of ammonia and nitre -	5	
Snow or pounded ice	12	From—18 to —25.
Common ſalt	5	
Nitrat of ammonia	5	
Snow and diluted nitric acid		From 0 to —46.
Snow - -	2	From —10 to—56.
Diluted ſulphuric acid	1	
Diluted nitric acid	1	
Snow - -	1	From 20 to —60.
Diluted ſulphuric acid	1	

In order to produce theſe effects, the ſalts employed muſt be freſh cryſtallized, and newly reduced to a very fine powder. The veſſels in which the freezing mixture is made ſhould be very thin, and juſt large enough to hold it, and the materials ſhould be mixed together as quickly as poſſible. The materials to be employed in order to produce great cold ought to be firſt reduced to the temperature marked in the table, by placing them in ſome of the other freezing mixtures; and then they are to be mixed together in a ſimilar freezing mixture. If, for inſtance, we wiſh to produce a cold = —46, the ſnow and diluted nitric acid ought to be cooled down to 0, by putting the veſſel which contains each of them into the 12th freezing mixture in the above table before they are mixed together. If a ſtill greater cold is required, the materials to produce it are to be brought to the proper temperature by being previouſly placed in the ſecond freezing mixture. This proceſs is to be continued till the required degree of cold has been procured†.

28
Subſta
which
tain
caloric

11. From the facts already known we may conclude, that the particles of caloric have two properties, that of repelling each other, and of attracting and being attracted by other ſubſtances. As there is no body in nature which does not contain caloric, we may ſafely conclude that there is no body in nature which has not an affinity for it. When it unites with bodies, though the repulſion of its particles may be overcome by their attraction for the particles of the body, and by the attraction

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† Wal
Phil.
1795.

quantity of caloric ; and we know for certain that caloric is evolved during condenſation. A thermometer placed within a condenſer riſes ſeveral degrees every time air is thrown in †. We can even ſee a reaſon for this. When the particles of a body are forced nearer each other, the repulſive power of the caloric combined with them is increaſed, and conſequently a part of it will be apt to fly off. Now, after a bar of iron has been heated by the hammer, it is much harder and brittler than before. It muſt then have become denſer, and conſequently muſt have parted with caloric. It is an additional confirmation of this, that the ſame bar cannot be heated a ſecond time by percuſſion until it has been expoſed for ſome time to a red heat. It is too brittle, and flies to pieces under the hammer. Now brittleneſs ſeems in moſt caſes owing to the abſence of the uſual quantity of caloric. Glaſs *unannealed*, or, which is the ſame thing, that has been cooled very quickly, is always extremely brittle. When glaſs is in a ſtate of fuſion, there is a vaſt quantity of caloric accumulated in it, the repulſion between the particles of which muſt of courſe be very great ; ſo great indeed, that they would be diſpoſed to fly off in every direction with inconceivable velocity, were they not confined by an unuſually great quantity of caloric in the ſurrounding bodies : conſequently if this ſurrounding caloric be removed, the caloric of the glaſs flies off at once, and more caloric will leave the glaſs than otherwiſe would leave it, becauſe the velocity of the particles muſt be greatly increaſed. Probably then the brittleneſs of glaſs is owing to the deficiency of caloric ; and we can ſcarcely doubt that the brittleneſs of iron is owing to the ſame cauſe, if we recollect that it is removed by the application of new caloric. Part therefore of the caloric which appears in conſequence of percuſſion ſeems to proceed from the body ſtruck ; and this is doubtleſs the reaſon why thoſe bodies, the denſity of which is not increaſed by percuſſion, as liquids and ſoft ſubſtances, are not heated at all.

† Darwin, Phil. Tranſ. 788.

306
nd partly
combuſ-
on.

We ſay *part* of the caloric, becauſe, often at leaſt, part of it is probably owing to another cauſe. By condenſation, as much caloric is evolved as is ſufficient to raiſe the temperature of ſome of the particles of the body high enough to enable it to combine with the oxygen of the atmoſphere. The combination actually takes place, and a great quantity of additional caloric is ſeparated by the decompoſition of the gas. That this happens during the colliſion of flint and ſteel cannot be doubted : for the ſparks produced are merely ſmall pieces of iron heated red hot by uniting with oxygen during their paſſage through the air, as any one may convince himſelf by actually examining them. Mr Lane has ſhewn that iron produces no ſparks in the vacuum of an air-pump ; but Mr Kirwan has obſerved that they are produced under common ſpring water ; and we know that iron at a certain temperature is capable of decompoſing water.

307
Sparks emitted by quartz ſtones on eliſion.

When quartz, rock-cryſtal (m), or other very hard ſtones, are ſtruck againſt one another, they emit ſparks. If they be often made to emit ſparks above a ſheet of white paper, there are found upon it a number of ſmall black bodies, not very unlike the eggs of flies. Theſe bodies are hard but friable, and when rubbed on the paper leave a black ſtain. When viewed with a microſcope, they ſeem to have been melted. Muriatic acid changes their colour to a green, as it does that of lavas.* Theſe ſubſtances evidently produced the ſparks by being heated red hot. Lamanon (n) ſuppoſes that they are particles of quartz combined with oxygen. Were that the caſe, the phenomenon would be preciſely ſimilar to that which is produced by the colliſion of flint and ſteel. That they are particles of quartz cannot be doubted ; but to ſuppoſe them combined with oxygen is contrary to all experience : for theſe ſtones never ſhew any diſpoſition to combine with oxygen even when expoſed to the moſt violent heat. La Metherie made experiments on purpoſe to ſee whether Lamanon's opinion was well founded ; but they all turned out unfavourable to it. And Monge aſcertained, that the particles deſcribed by Lamanon were pure cryſtal unaltered, with a quantity of black powder adhering to them. He concludes accordingly, that theſe fragments had been raiſed to ſo high a temperature during their paſſage through the air, that they ſet fire to all the minute bodies that came in their way †. We muſt therefore either ſuppoſe that all the caloric was produced by mere condenſation, which is not probable, or acknowledge that we cannot explain the phenomenon.

* Lamanon, Journ. de Phyſ. 1785.

308
Cauſe of this unknown.

† Ann. de Chim. xvi. 206.

309
Emiſſion of caloric on friction,

16. Caloric is not only produced by percuſſion, but alſo by friction. Fires are often kindled by rubbing pieces of dry wood ſmartly againſt one another. It is well known that heavy loaded carts ſometimes take fire by the friction between the axle-tree and the wheel.

310
Not owing to condenſation,

Now in what manner is the caloric evolved or accumulated by friction ? Not by increaſing the denſity of the bodies rubbed againſt each other, as happens in caſes of percuſſion ; for heat is produced by rubbing ſoft bodies againſt each other, the denſity of which therefore cannot be increaſed by that means, as any one may convince himſelf by rubbing his hand ſmartly againſt his coat. It is true, indeed, that heat is not produced by the friction of liquids, but then they are too yielding

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(m) Theſe ſtones are compoſed of almoſt pure ſilica.

(n) This ingenious and unfortunate young man, to whom we are indebted for theſe facts, fell a victim to his ardour for knowledge. He accompanied La Peyrouſe in his laſt voyage, and was murdered with the moſt ſavage cruelty, together with La Langle and ſeveral others, by the natives of the iſland of Maouna. When a man of genius, anxious to acquire honeſt fame, and a man too ſo nobly diſintereſted as Lamanon, thus falls prematurely before he has attained the object of his wiſhes,

> " Cut off from nature's and from glory's courſe !
> " Which never mortal was ſo fond to run,"

who can withhold the tribute of regret and admiration, when they

> ——" conjecture what he might have proved,
> " And think life only wanting to his fame."

to be ſubjected to ſtrong friction. It is not owing to the ſpecific caloric of the rubbed bodies decreaſing; for Count Rumford found, that there was no ſenſible decreaſe†: nor, if there were a decreaſe, would it be ſufficient to account for the vaſt quantity of heat which is ſometimes produced by friction.

311
Nor to decreaſe of ſpecific caloric,

Count Rumford took a cannon caſt ſolid and rough as it came from the foundery; he cauſed its extremity to be cut off, and formed, in that part, a ſolid cylinder attached to the cannon, $7\frac{1}{4}$ inches in diameter, and $9\frac{8}{10}$ inches long. It remained joined to the reſt of the metal by a ſmall cylindrical neck. In this cylinder a hole was bored 3,7 inches in diameter, and 7,2 inches in length. Into this hole was put a blunt ſteel borer, which by means of horſes was made to rub againſt its bottom; at the ſame time a ſmall hole was made in the cylinder perpendicular to the bore, and ending in the ſolid part a little beyond the end of the bore. This was for introducing a thermometer to meaſure the heat of the cylinder. The cylinder was wrapt round with flannel to keep in the heat. The borer preſſed againſt the bottom of the hole with a force equal to about 10,000lb. avoirdupois, and the cylinder was turned round at the rate of 32 times in a minute. At the beginning of the experiment the temperature of the cylinder was 60°; at the end of 30 minutes, when it had made 960 revolutions, its temperature was 130°. The quantity of metallic duſt or ſcales produced by this friction amounted to 837 grains. Now, if we were to ſuppoſe that all the caloric was evolved from theſe ſcales, as they amounted to juſt $\frac{1}{948}$ part of the cylinder, they muſt have given out 948° to raiſe the cylinder 1°, and conſequently 66360° to raiſe it 70° or to 130°, which is certainly incredible†.

312
Nor to combuſtion,

Neither is the caloric evolved during friction, owing to the combination of oxygen with the bodies themſelves or any part of them. By means of a piece of clockwork, Mr Pictet made ſmall cups (fixed on the axis of one of the wheels) to move round with conſiderable rapidity, and he made various ſubſtances rub againſt the outſides of theſe cups, while the bulb of a very delicate thermometer placed within them marked the heat produced. The whole machine was of a ſize ſufficiently ſmall to be introduced into the receiver of an air pump. By means of this machine a piece of adamantine ſpar was made to rub againſt a ſteel cup in air: ſparks were produced in great abundance during the whole time, but the thermometer did not riſe. The ſame experiment was repeated in the exhauſted receiver of an air pump (the manometer ſtanding at four lines); no ſparks were produced, but a kind of phoſphoric light was viſible in the dark. The thermometer did not riſe. A piece of braſs being made to rub in the ſame manner againſt a much ſmaller braſs cup in air, the thermometer (which almoſt filled the cup) roſe 0,3°, but did not begin to riſe till the friction was over. This ſhews us that the motion produced in the air carried off the caloric as it was evolved. In the exhauſted receiver it began to riſe the moment the friction began, and roſe in all 1,2° When a bit of wood was made to rub againſt the braſs cup in the air, the thermometer roſe 0,7°, and on ſubſtituting alſo a wooden cup it roſe 2,1°, and in the exhauſted receiver 2,4°, and in air condenſed to $1\frac{3}{4}$ atmoſpheres it roſe 0,5°*.

If theſe experiments be not thought concluſive, we have others to relate which will not leave a doubt that the heat produced by friction is not connected with the decompoſition of oxygen gas. Count Rumford contrived, with his uſual ingenuity, to incloſe the cylinder above deſcribed in a wooden box filled with water, which effectually excluded all air, as the cylinder itſelf and the borer were ſurrounded with water, and at the ſame time did not impede the motion of the inſtrument. The quantity of water amounted to 18,77lbs. avoirdupois, and at the beginning of the experiment was at the temperature of 60°. After the cylinder had revolved for an hour at the rate of 32 times in a minute, the temperature of the water was 107°; in 30 minutes more it was 178°; and in 2 hours and 30 minutes after the experiment began, the water *actually boiled*. According to the computation of Count Rumford, the caloric produced would have been ſufficient to heat 26,58lbs. avoirdupois of ice-cold water boiling hot; and it would have required 9 wax candles of a moderate ſize, burning with a clear flame all the time the experiment laſted, to have produced as much heat. In this experiment all acceſs of water into the hole in the cylinder where the friction took place was prevented. But in another experiment the reſult of which was preciſely the ſame, the water was allowed free acceſs†.

313
And conſequently at preſent inexplicable.

The caloric, then, which appears in conſequence of friction, is neither produced by an increaſe of the denſity, nor by an alteration in the ſpecific caloric of the ſubſtances expoſed to friction, nor is it owing to the decompoſition of the oxygen of the atmoſphere—Whence then is it derived? This queſtion we are altogether unable to anſwer. We cannot, however, think, that the concluſion which Count Rumford is diſpoſed to draw from his experiments is warranted by the premiſes. He ſuppoſes, that becauſe we cannot explain the manner that caloric is accumulated by friction, there is no ſuch ſubſtance as caloric at all, but that it is merely a *peculiar kind of motion*. We would beg leave to aſk, how the facts mentioned in the former part of this chapter, many of which were furniſhed by this ingenious philoſopher himſelf, and all of which combine to render the exiſtence of caloric as a ſubſtance probable, can be deſtroyed and ſet aſide, merely becauſe there are other phenomena in nature connected with caloric which cannot be accounted for? Were it poſſible to prove that the accumulation of caloric by friction is *incompatible* with its being a ſubſtance, in that caſe Count Rumford's concluſion would be a fair one; but this ſurely has not been done. We are certainly not yet ſufficiently acquainted with the laws of the motion of caloric (allowing it to be a ſubſtance) to be able to affirm with certainty that friction could not cauſe it to accumulate in the bodies rubbed. This we know at leaſt to be the caſe with electricity. Nobody has been hitherto able to demonſtrate in what manner it is accumulated by friction; and yet this has not been thought a ſufficient reaſon to deny its exiſtence.

314
This no proof that caloric is not a body

315
Analogy between caloric and electricity.

Indeed there ſeems to be a very cloſe analogy between caloric and electric matter. Both of them tend to diffuſe themſelves equally, both of them dilate bodies, both of them fuſe metals, and both of them kindle combuſtible ſubſtances. Mr Achard has proved, that electricity can be ſubſtituted for caloric even in thoſe caſes where its agency ſeems peculiarly neceſſary; for he found that, by conſtantly ſupplying a certain quantity of the electric

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† *Nicholſon's Journal*, ii. 106.

† *Ibid.*

* *Pictet ſur le Feu*, ch. 9.

† *Nicholſon ibid.*

321
Inflection, deflection,

When light paſſes within a certain diſtance of a body, parallel to which it is moving, it is bent *towards* it; when it paſſes at a greater diſtance, it is bent *from* it. The firſt of theſe properties is called *inflection*, the ſecond *deflection*. Now the rays differ in theſe properties in the order in which they were named; the red being *moſt*, the violet *leaſt* inflexible and deflexible. This was ſuſpected by David Rittenhouſe,* but was firſt demonſtrated by the ingenious experiments of Mr Brougham †.

322
And reflexity.

When light falls upon a viſible body, ſome of it is reflected back; and the more poliſhed or the whiter any ſurface is, the more light it reflects. The rays of light differ alſo in reflexity (ſee Reflexity, *Suppl.)*, the red being the moſt, the violet the leaſt reflexible. This diſcovery we owe to the ſame ingenious gentleman ‡.

Theſe properties of light conſtitute the ſubject of Optics; to which we refer thoſe who wiſh to ſee them inveſtigated. We mention them here becauſe they prove that light is acted on by other bodies, that it is ſubjected to the laws of attraction, and, conſequently, that it poſſeſſes *gravity*.

2. The particles of light ſeem alſo, like thoſe of caloric, to poſſeſs the property of repelling one another; at leaſt their rapid motion, in all directions, from luminous bodies, ſeems to be owing to ſome ſuch property.

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Light capable of entering bodies,

3. Light is capable of entering into bodies, and remaining in them, and of being afterwards extricated without any alteration. Father Beccaria, and ſeveral other philoſophers, have ſhown us by their experiments, that there are a great many ſubſtances which become luminous after being expoſed to the light. This property was diſcovered by carrying them inſtantly from the light into a dark place, or by darkening the chamber in which they were expoſed. Moſt of theſe ſubſtances, indeed, loſe this property in a very ſhort time, but they recover it again on being expoſed to the light; and this may be repeated as often as we pleaſe. We are indebted to Mr Canton for ſome very intereſting experiments on this ſubject, and for diſcovering a compoſition which poſſeſſes this property in a remarkable degree. He calcined ſome common oyſter ſhells in a good coal fire for half an hour, and then pounded and ſifted the pureſt part of them. Three parts of this powder were mixed with one part of the flowers of ſulphur, and rammed into a crucible which was kept red hot for an hour. The brighteſt parts of the mixture were then ſcraped off, and kept for uſe in a dry phial well ſtopped. When this compoſition is expoſed for a few ſeconds to the light, it becomes ſufficiently luminous to enable a perſon to diſtinguiſh the hour on a watch by it. After ſome time it ceaſes to ſhine, but recovers this property on being again expoſed to the light. Light then is not only acted upon by other bodies, but it is capable of uniting with them, and afterwards leaving them without any change.

It is well known that light is emitted during combuſtion; and it has been objected to this concluſion, that theſe bodies are luminous only from a ſlow and imperceptible combuſtion. But ſurely combuſtion cannot be ſuſpected in many of Father Beccaria's experiments, when we reflect that one of the bodies on which they were made was his own hand, and that many of the others were altogether incombuſtible; and the phenomena obſerved by Mr Canton are alſo incompatible with the notion of combuſtion. His pyrophorus ſhone only in conſequence of being expoſed to light, and loſt that property by being kept in the dark. It is not expoſure to light which cauſes ſubſtances capable of combuſtion at the temperature of the atmoſphere to become luminous, but expoſure to air. If the ſame temperature continues, they do not ceaſe to ſhine till they are conſumed; and if they ceaſe, it is not the applicacation of light, but of caloric, which renders them again luminous: but Canton's pyrophorus, on the contrary, when it had loſt its property of ſhining, did not recover it by the application of heat, except it was accompanied by light. The only effect which heat had was to increaſe the ſeparation of light from the pyrophorus, and of courſe to ſhorten the duration of its luminouſneſs. Two glaſs globes, hermetically ſealed, containing each ſome of this pyrophorus, were expoſed to the light and carried into a dark room. One of them, on being immerſed in a baſon of boiling water, became much brighter than the other, but in ten minutes it ceaſed to give out light: the other remained viſible for more than two hours. After having been kept in the dark for two days, they were both plunged into a baſon of hot water; the pyrophorus which had been in the water formerly did not ſhine, but the other became luminous, and continued to give out light for a conſiderable time. Neither of them afterwards ſhone by the application of hot water; but when brought near to an iron heated ſo as ſcarcely to be viſible in the dark, they ſuddenly gave out their remaining light, and never ſhone more by the ſame treatment: but when expoſed a ſecond time to the light, they exhibited over again preciſely the ſame phenomena; even a lighted candle and electricity communicated ſome light to them. Surely theſe facts are altogether incompatible with combuſtion, and fully ſufficient to convince us that light alone was the agent, and that it had actually entered into the luminous bodies.

It has been queſtioned, indeed, whether the light emitted by pyrophori be the ſame with that to which they are expoſed. Mr Wilſon has proved, that in many caſes at leaſt it is different, and in particular that on many pyrophori the blue rays have a greater effect than any other, and that they cauſe an extrication of red light. Mr de Groſſer has ſhewn the ſame thing with regard to the diamond, which is a natural pyrophorus ‡. Still, however, it cannot be queſtioned that the luminouſneſs of theſe bodies is owing to expoſure to light, and that the phenomenon is not connected with combuſtion.

324
And of ing con ned wit them.

But light appears capable, not only of entering into bodies, but of combining with them chemically. The phenomena of the phoſphori ſeem to be inſtances of this, and a great many facts concur to prove that light enters into the compoſition of oxygen gas. When vegetables grow in the light, they give out oxygen gas; but no oxygen is extricated in the dark, even though heat be applied †. From this it is evident, that the ſeparation of this gas from plants, or perhaps the decompoſition of the water which they contain, depends upon the action of light; and that as this decompoſition is chemical, the light to produce it muſt either combine with the oxygen or the hydrogen, or at leaſt contribute to the combination of ſome other ſubſtance with one or other of them. When the oxyds of gold or ſilver are expoſed

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* *Tranſ. Philad.* ii.

† *Phil. Tran.* 1796.

‡ *Phil. Tranſ. ibid.*

‡ *Jour.* *Phyſ.* xx 270.

† *Prieſtl. and Inge. houſz.*

Light.

Scheele. Berthollet.

expoſed to light, they are reduced to the metallic ſtate,* and at the ſame time a quantity of oxygen gas is extricated.‡ In this caſe, it is evident that the light muſt either combine with the oxygen or the metals. If a quantity of nitric acid be expoſed for ſome time to the light, it becomes yellow, as is well known, and a quantity of oxygen gas is found floating on its top. If it be now carried to a dark place, the oxygen is gradually abſorbed, and the acid becomes colourleſs. In this caſe, nitric acid is decompoſed by means of light, and reſolved into *nitrous acid* and oxygen gas. The light muſt therefore have combined either with the nitrous acid or the oxygen. But no change whatever appears to have been produced in the nitrous acid; for if it be obtained in the dark by any other proceſs, it has preciſely the ſame properties. The oxygen, on the contrary, is converted into a *gas*. It is more probable, then, that the light has combined with the oxygen than with the acid. Hence there is reaſon to ſuſpect that light makes one of the ingredients of oxygen gas. Caloric has already been ſhewn to make another ingredient.

325 ht ch ap- rs dur- com- ion ſup- d com- d with gen gas.

During combuſtion, a quantity of light as well as caloric is almoſt always evolved. We muſt conclude, therefore, that light makes a part of the compoſition either of the combuſtibles themſelves, or of the oxygen gas with which they unite. We have already ſhewn, that oxygen gas probably contains light; and this probability is confirmed by another fact. Subſtances may be combined with oxygen without the emiſſion of any light, provided the oxygen be not in the ſtate of a gas. If phoſphorus, for inſtance, be put into nitric acid, it attracts oxygen, and is converted into phoſphoric acid without the emiſſion of any light. Now if the light which appears during combuſtion had been combined with the combuſtible, it ought to appear in all caſes when that combuſtible is united with oxygen, whether the oxygen has previouſly been in the ſtate of a gas or not. But as this is not the caſe, we may certainly infer, that the light which appears during combuſtion is extricated, not from the combuſtible, but from the oxygen gas. And this ſeems at preſent to be the opinion of the greater number of philoſophers.

But we muſt acknowledge, that this concluſion is not without its difficulties, and difficulties, too, which, in the preſent ſtate of chemiſtry, it does not ſeem poſſible to ſurmount.

326 iculties anding t opi- n.

In the firſt place, it is evident, that light *may* be produced during combuſtion, though the oxygen be not in the ſtate of a gas: For if nitric acid be poured upon oil of turpentine, the oil takes fire, and burns with the greateſt rapidity, and a great deal of light is emitted. This combuſtion is occaſioned by the oxygen of the acid combining with the ingredients of the oil. It follows, therefore, if the light emitted was previouſly combined with the oxygen, that oxygen muſt contain light when not in the ſtate of a gas. Mr Prouſt has ſhown that a great variety of ſimilar combuſtions may be produced. But what is very remarkable, by proper caution the very ſame combinations may be made to take place without the viſible emiſſion of any light. In that caſe they take place very ſlowly, as happens alſo when phoſphorus decompoſes nitric acid; ſo that the emiſſion or non-emiſſion of light ſeems to depend not upon the ſtate of the oxygen, ſo much as upon the rapidity or ſlowneſs of the combination. It is true, indeed, as the late Dr Hutton of Edinburgh obſerved, that light may be emitted in theſe ſlow combinations though it be not viſible: and this is very probably the caſe; but then the proof is deſtroyed that light exiſts in oxygen gas, from its not appearing during combinations in which the oxygen did not exiſt previouſly in a gaſeous ſtate.

In the ſecond place, the colour of the light emitted during combuſtion differs almoſt always according to the combuſtible. During the combuſtion of phoſphorus, tin, and zinc, the light emitted is white; during that of ſulphur and biſmuth, blue. Now if this light were united with the oxygen, why does it not appear always of the ſame colour, whatever be the combuſtible?

In the laſt place, the phenomena of phoſphori ſhew that light is capable of entering into other bodies as well as oxygen gas; and the emiſſion of light on the colliſion of two flint ſtones, when no oxygen gas can be decompoſed, is a proof of the ſame kind, which cannot be got over.

In the preſent ſtate of chemiſtry, therefore, it cannot be concluded, that the light emitted during combuſtion does not exiſt in the combuſtibles as well as in the oxygen.

327 Light heats bodies.

4. Light has the property of heating bodies. All bodies, however, are not heated by it. Thoſe which are perfectly tranſparent, or which allow all the light to paſs through them, ſuffer no alteration in their temperature. Thus light may be concentrated upon water or glaſs without producing any effect. Neither does it produce much change upon thoſe bodies (mirrors for inſtance) that reflect all or nearly all the light which falls upon them. And the ſmallneſs of the alteration of temperature is always proportional to the fineneſs of the poliſh, or, which is the ſame thing, to the quantity of light which is reflected. So that we have reaſon to conclude, that if a ſubſtance could be procured which reflected all the light that fell upon it, the temperature of ſuch a ſubſtance would not be at all affected by light falling upon it. Dr Franklin expoſed upon ſnow pieces of cloth of different colours (white, red, blue, black), to the light of the ſun, and found that they ſunk deeper, and conſequently acquired heat, in proportion to the darkneſs of their colour. Now it is well known that dark-coloured bodies, even when equally expoſed to the light, reflect leſs of it than thoſe which are light-coloured. But ſince the ſame quantity falls upon each, it is evident that dark coloured bodies muſt abſorb and retain more of it than thoſe which are light-coloured. That ſuch an abſorption actually takes place is evident from the following experiment. Mr Thomas Wedgewood placed two lumps of luminous or phoſphoreſcent marble on a piece of iron heated juſt under redneſs. One of the lumps of marble which was blackened over gave out no light; the other gave out a great deal. On being expoſed a ſecond time in the ſame manner, a faint light was ſeen to proceed from the clean marble, but none at all could be perceived to come from the other. The black was now wiped off, and both the lumps of marble were again placed on the hot iron: The one that had been blackened gave out juſt as little light as the other §. In this caſe, the light which ought to have proceeded from the luminous marble diſappeared: it muſt therefore have been

ſtopped

§ *Phil. Tran.* 1792.

that of combination, the moment light entered a body it ought to be no longer light but caloric, and conſequently ought to produce preciſely the ſame effects with caloric: And ſince this is not the caſe, we are warranted ſurely to conclude that light and caloric are not the ſame, but different ſubſtances. How then does caloric occaſion the appearance of light, and light that of caloric?

331 Suppoſed wing to he mutual epulſion of ight and aloric.

We have ſeen already, that there is no body in nature which does not contain caloric; and light has ſuch an influence upon every thing, it produces ſuch important changes upon the animal and vegetable kingdoms, it can be extricated from ſuch a vaſt number of bodies, that in all probability we may conclude, with regard to it alſo, that it exiſts in all, or in almoſt all, the bodies in nature. We have no means of aſcertaining either the quantity of light or of caloric that exiſts in bodies; but if we were to judge from the quantity which appears during combuſtion, we muſt reckon it very conſiderable. Now, may there not exiſt a repulſion between the particles of caloric and light? It is not eaſy, at leaſt, to ſee why light flies off during combuſtion with ſuch rapidity, if this be not the caſe. If ſuch a repulſion actually exiſts, it will follow that caloric and light cannot be accumulated in the ſame body beyond a certain proportion. If the caloric exceed, it will tend to drive off the light; if the light, on the contrary, happens to prevail, it will diſplace the caloric.

If caloric and light actually exiſt in all bodies, there muſt be an affinity between them and all other bodies; and this affinity muſt be ſo great, as to render ineffectual the repulſion which exiſts between light and caloric. Let us ſuppoſe now, that theſe two ſubſtances exiſt in all bodies in certain proportions, it will follow, that the more either of caloric or light is added to any body, the ſtronger muſt the repulſion between their particles become; and if the accumulation be ſtill going on, this repulſion will ſoon become great enough to balance their affinity for the body in which they exiſt, and conſequently will diſpoſe them to fly off. If caloric, for inſtance, be added to a body, whenever the body arrives at a certain temperature it becomes luminous, becauſe part of the light which was formerly combined with it is driven off. This temperature muſt depend partly upon the affinity between the body and caloric, and partly upon its affinity for light. Pyrophori, for inſtance, the affinity between which and light does not ſeem to be very great, become luminous at a very moderate temperature. This is the caſe with the pyrophorus of Canton. A great many hard bodies become luminous when they are expoſed to a moderate heat; fluor, for inſtance, carbonat of barytes, ſpar, ſea ſhells, and a great many others, which are enumerated by Mr Thomas Wedgewood.*

The ſame ingenious gentleman has obſerved, that gold, ſilver, copper, and iron, become luminous when

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* Phil. Tranſ. 1792, p. 1.

viſible in the dark; in the other was placed the bulb of a thermometer. In ſix minutes the thermometer roſe from 4° to 14° (*Reaumur*). A lighted candle, which was ſubſtituted for the ball of iron, made the thermometer riſe in one experiment from 4,6° to 14°; in another, from 4,2° to 14,3°. In this caſe both light and heat appeared to act. In order to ſeparate them, he interpoſed between the two mirrors a plate of clear glaſs. Before the interpoſition of the glaſs, the thermometer had riſen from 2° to 12°, where it was ſtationary. After the interpoſition of the glaſs it ſunk in nine minutes to 5,7°; and when the glaſs was again removed it roſe in ſeven minutes to 11,1°; yet the light which fell on the thermometer did not ſeem at all diminiſhed by the glaſs. Mr Pictet therefore concluded, that the caloric had been reflected by the mirror, and that it had been the cauſe of the riſe of the thermometer. In another experiment, a glaſs matraſs was ſubſtituted for the iron ball, nearly of the ſame diameter with it, and containing 2044 grains of boiling water. Two minutes after a thick ſcreen of ſilk, which had been interpoſed between the two mirrors, was removed, a Fahrenheit's thermometer, which was in the other focus, roſe from 47° to 50$\frac{1}{8}$; and the moment the matraſs was removed from the focus the thermometer again deſcended. On repeating the experiment, with this variation, that the bulb of the thermometer was blackened, it roſe from 51$\frac{1}{8}$ to 55$\frac{1}{4}$.

The mirrors of tin were now placed at the diſtance of 90 inches from each other; the matraſs with the boiling water in one of the foci, and a very ſenſible air thermometer in the other, every degree of which was equal to $\frac{1}{20}$th of a degree of Reaumur. Exactly in the middle ſpace between the two mirrors there was placed a very thin common glaſs mirror, ſuſpended in ſuch a manner that either ſide could be turned towards the matraſs. When the poliſhed ſide of this mirror was turned to the matraſs, the thermometer roſe only 0,5°; but when the ſide covered with tinfoil, and which had been blackened with ink and ſmoke, was turned toward the matraſs, the thermometer roſe 3,5°. In another experiment, when the poliſhed ſide of the mirror was turned to the matraſs, the thermometer roſe 3°, when the other ſide 9,2°. On rubbing off the tinfoil, and repeating the experiment, the thermometer roſe 18°. On ſubſtituting for the glaſs mirror a piece of thin white paſteboard of the ſame dimenſions with it, the thermometer roſe 10°. On putting a matraſs full of ſnow into one of the foci (the mirrors in this experiment were 10½ feet diſtant from each other), the air thermometer *ſunk* ſeveral degrees, and roſe again when the matraſs was removed. When nitric acid was poured on the ſnow, the thermometer ſunk 5° or 6° lower.

Taking it for granted that theſe experiments proved the motion of caloric in ſtraight lines like light, Mr Pictet endeavoured to diſcover the velocity of its motion. For this purpoſe he placed two concave mirrors at the diſtance of 69 feet from each other; the one of tin as before, the other of plaſter gilt, and 18 inches in diameter. Into the focus of this laſt mirror he put the air thermometer, and the bullet of iron heated as before into that of the other. A few inches from the face of the tin mirror there was placed a thick ſcreen, which was removed as ſoon as the bullet reached the focus. The thermometer roſe the inſtant the ſcreen was removed without any perceptible interval: hence he concluded, that the time caloric takes in moving 69 feet is too ſhort to be meaſured. See *Pictet ſur le Feu*, chap. iii.

We

have meant *hydrogen*. It is needleſs therefore to examine his theory, as it is now known that the combination of hydrogen and oxygen forms not caloric but water (u). The whole fabric therefore has tumbled to the ground; but the importance of the materials will always be admired, and the ruins of the ſtructure ſhall remain eternal monuments of the genius of the builder.

334 De Luc's theory

Mr de Luc, ſo well known for his important meteorological labours, has advanced another theory*. According to him, light is a body which moves conſtantly in ſtraight lines, with ſuch rapidity that its gravitation towards other ſubſtances bears no ſenſible proportion to its motion. Light has the property of combining with another unknown ſubſtance, and the compound formed is caloric, which poſſeſſes very different properties from light. Caloric is conſtantly deſcribing helicoidal curves round an axis, which accounts for the ſlowneſs of its apparent motion. Light produces or increaſes heat, partly by increaſing the expanſive power of caloric, and partly by combining with the *unknown ſubſtance*, and forming new caloric; caloric, on the other hand, is always decompoſed when bodies become luminous. This theory is certainly ingenious, and would remove many of the difficulties which we at preſent labour under in attempting to explain the phenomena of caloric and light. It is, however, liable to other difficulties, which could not be eaſily ſurmounted. But it is needleſs to examine theſe, as the theory itſelf is ſupported by no evidence whatever, and cannot therefore be admitted.

* In his *Idées ſur la Meteorologie.*

335 Hutton's theory.

Another theory has been advanced by the late Dr Hutton of Edinburgh (v); a man of undoubted genius, but of rather too ſpeculative a turn of mind, and who ſometimes involved himſelf in difficulties from his very ingenuity. All his writings diſplay evident marks of the profound philoſopher: they contain much inſtruction; and even his miſtakes are not without their uſe: but unfortunately his manner is ſo peculiar, that it is ſcarcely more difficult to procure the ſecrets of ſcience from Nature herſelf, than to dig them from the writings of this philoſopher. He ſuppoſes that there are two kinds of matter, gravitating matter and light; the laſt of which wants gravity, and conſequently neither poſſeſſes magnitude (w) nor momentum. Light has the power of being fixed in bodies; and then it becomes either caloric or phlogiſton, which differs in ſome particulars from caloric, but in what, the Doctor does not preciſely tell us.

Part of this theory we have examined already when we attempted to prove that light and caloric were different ſubſtances. The other part of the theory ſeems to involve a contradiction; for how could light become fixed in a body, unleſs it were attracted by it? and if light poſſeſſes attraction, it ſurely cannot be deſtitute of gravity; for what is gravity but *attraction* (x)?

Thus, notwithſtanding the ingenuity of the philoſophers who have attempted to inveſtigate this part of chemiſtry, the connection between light and caloric is ſtill unknown. We muſt content ourſelves, therefore, with conſidering them at preſent as diſtinct ſubſtances, and leave the ſolution of the many difficulties which at preſent perplex us to the more happy labours of future enquirers.

PART II. OF COMPOUND BODIES.

TO thoſe bodies, which are compoſed of *two ſimple ſubſtances* combined together, for want of a better name we have given the appellation of *compound bodies*. They may be reduced under five claſſes:

1. Water;
2. Alcohol;
3. Oils;
4. Alkalies;
5. Acids.

Theſe ſhall be the ſubject of the five following chapters; and we ſhall finiſh this part of the article with ſome obſervations on *Affinity*.

CHAP. I. *Of* WATER.

WATER is a well-known liquid, found in abundance in every part of the world, and abſolutely neceſſary for the exiſtence of animals and vegetables.

When pure, in which ſtate it can be obtained only by diſtillation, it is tranſparent, and deſtitute of colour taſte, and ſmell.

336 Weight of water.

A cubic foot of water, at the temperature of 55°, weighs, according to the experiments of Profeſſor Robiſon of Edinburgh (ſee SPECIFIC *Gravity*, Encycl.), 998,74 avoirdupois ounces, of 437,5 grains troy each, or only 1,26 ounces leſs than 1000 avoirdupois ounces; ſo that rain water, at the ſame temperature, will weigh pretty nearly 1000 ounces. The ſpecific gravity of water is always ſuppoſed = 1,000, and it is made the meaſure of the ſpecific gravity of every other body.

337 Ice.

When water is cooled down to 32°, it aſſumes the form of ice. If this proceſs goes on very ſlowly, the ice aſſumes the form of cryſtalline needles, croſſing each other at angles either of 60° or 120°, as Mr de Mairan has remarked; and it has been often obſerved in large cryſtals of determinate figures. Ice, while kept at a temperature conſiderably below 32°, is very hard, and may be pounded into the fineſt duſt. It is elaſtic. Its ſpecific gravity is leſs than that of water.

When

(u) This candid philoſopher afterwards acknowledged, that the proofs for the compoſition of water were complete; but we do not know exactly how he attempted to reconcile his theory of heat with the belief that water was compoſed of oxygen and hydrogen; two opinions which are certainly incompatible.

(v) See his diſſertations on different ſubjects of natural philoſophy.

(w) Indeed Dr Hutton refuſed this property to gravitating matter alſo; following, in this particular, the theory of the celebrated Boſcovich.

(x) We hope not to be accuſed of diſputing merely about the meaning of a word, till what is ſaid on this ſubject in the chapter of the preſent article, which treats of *Affinity*, has been examined.

38 am.

When water is heated to the temperature of 212°, it boils, and is gradually converted into ſteam. Steam is an inviſible fluid like air, but of a leſs ſpecific gravity. It occupies about 1200 times the ſpace that water does. Its elaſticity is ſo great, that it produces the moſt violent exploſions when confined. It is upon this principle that the ſteam-engine has been conſtructed. See STEAM and STEAM-*Engine*, Encycl.

39 Bo ng poi of wa

The phenomena of boiling are owing entirely to the rapid formation of ſteam at the bottom of the veſſel. The boiling point of water varies according to the preſſure of the atmoſphere. In a vacuum water boils at 90°; and when water is confined in Papin's digeſter, it may be almoſt heated red hot without boiling.

40 Im egnat- ed ith va- rio ſalts.

The mixture of various ſalts with water affect its boiling point conſiderably. Mr Achard made a number of experiments on that ſubject: the reſult of which may be ſeen in the following tables‡.

CLASS I. *Salts which do not affect the Boiling Point.*

Sulphat of copper.

CLASS II. *Salts which raiſe the Boiling Point.*

A ſaturated ſolution of	Raiſes the boiling point
Muriat of ſoda	10,35°
Sulphat of ſoda	5,6
Sulphat of potaſs	0,9
Nitrat of potaſs	3,5
Boracic acid	2,2
Carbonat of ſoda	2,35

This augmentation varies with the quantity of ſalt diſſolved. In general, it is the greater the nearer the ſolution approaches to ſaturation.

CLASS III. *Salts which lower the Boiling Point.*

Borax,	In a ſmall quantity, lowers the boiling point - - - -	1,350°
	Saturated ſolution of, - -	0,22
Sulphat of magneſia,	In a ſmall quantity,	2,47
	Saturated ſolution of	1,1
Alum,	A very ſmall quantity of, - -	0,0
	A greater quantity, - -	0,7
	A ſaturated ſolution of, -	0,0
Sulphat of lime,	in any proportion,	2,02
Sulphat of zinc,		0,45
Sulphat of iron,		0,22
Acetite of lead,		1,24

CLASS IV.

Muriat of ammonia,	Small quantity of, lowers the boiling point, - - -	0,45
	Saturated ſolution of, raiſes do.	9,79
Carbonat of potaſs,	Small quantity of, lowers do. -	0,45
	Saturated ſolution of, raiſes do.	11,2

341 ter ipreſ- ſe.

Water was once ſuppoſed to be incompreſſible; but the contrary has been demonſtrated by Mr Canton. The Abbé Mongez made a number of experiments, long after that philoſopher, on the ſame ſubject, and obtained ſimilar reſults.

342 inion ut its ure.

Water was believed by the ancients to be one of the four elements of which every other body is compoſed; and, according to Hippocrates, it was the ſubſtance which nouriſhes and ſupports plants and animals. That water was an unchangeable element continued to be believed till the time of Van Helmont, who made plants grow for a long time in pure water: From which experiment it was concluded, that water was convertible into all the ſubſtances found in vegetables.—Mr Boyle having digeſted pure water in a glaſs veſſel hermetically ſealed for above a year, obtained a quantity of earthy ſcales; and concluded, in conſequence, that he had converted it partly into an earth.* He obtained the ſame earth by diſtilling water in a tall glaſs veſſel over a ſlow fire†. Margraf repeated the experiment with the ſame reſult, and accordingly drew the ſame concluſion. But the opinion of theſe philoſophers was never very generally received. The laſt perſon who embraced it was probably Mr Waſelton, who publiſhed his experiments on the ſubject in the Journal de Phyſique for 1780. Mr Lavoiſier had proved, as early as 1773, that the glaſs veſſels in which the diſtillation was performed loſt a weight exactly equal to the earth obtained. Hence it follows irreſiſtibly, that the appearance of the earth, which was ſilica, proceeded from the decompoſition of the veſſels; for glaſs contains a large proportion of ſilica. It has been ſince ſhown by Dr Prieſtley, that water always decompoſes glaſs when applied to its ſurface for a long time in a high temperature.

343 Hiſtory of the diſcovery of its compoſition.

We have formerly mentioned, that water is compoſed of oxygen and hydrogen. This great diſcovery has contributed more perhaps than any other to the advancement of the ſcience of chemiſtry, by furniſhing a key for the explanation of a prodigious number of phenomena. The evidence, therefore, on which it reſts, and the objections which have been made to it, deſerve to be examined with peculiar attention.

The firſt perſon probably who attempted to diſcover what was produced by burning hydrogen gas was Scheele. He concluded, that during the combuſtion oxygen and hydrogen combined, and that the product was caloric.

In 1776 Macquer, aſſiſted by Sigaud de la Fond, ſet fire to a bottle full of hydrogen gas, and placed a ſaucer above the flame, in order to ſee whether any fuliginous ſmoke would be produced. The ſaucer remained perfectly clean; but it was moiſtened with drops of a clear liquid, which they found to be pure water ‡.

Next year Bucquet and Lavoiſier exploded oxygen and hydrogen gas, and made an attempt to diſcover what was the product; about the nature of which they had formed different conjectures. Bucquet had ſuppoſed that it would be carbonic acid gas; Lavoiſier, on the contrary, ſuſpected that it would be ſulphuric or ſulphurous acid. What the product was they did not diſcover; but they proved that no carbonic acid gas was formed, and conſequently that Mr Bucquet's hypotheſis was ill founded ||.

In the beginning of the year 1781, Mr Warltire, at the requeſt of Dr Prieſtley, fired a mixture of theſe two gaſes contained in a copper veſſel; and obſerved, that after the experiment the weight of the whole was diminiſhed. Dr Prieſtley had previouſly, in the preſence of Mr Warltire, performed the ſame experiment in a glaſs veſſel. This veſſel became moiſt in the inſide, and was covered with a ſooty ſubſtance §, which Dr Prieſtley afterwards ſuppoſed to be a part of the mercury uſed in filling the veſſel*.

In the ſummer of 1781, Mr Henry Cavendiſh, who had been informed of the experiments of Prieſtley and Warltire,

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‡ nſ. Be n, 17.

* *Shaw's Boyle*, iii. 417.

† *Ibid*, i. 267.

‡ *Macquer's Dictionary.* art. *Gas inflammable.*

|| *Mem. Par.* 1781. 470.

§ *Prieſtley*, v. 395.

* *Phil. Tranſ.* lxxiv. 332.

Warltire, ſet fire to 500,000 grain meaſures of hydrogen gas, mixed with about 2½ times that quantity of common air. By this proceſs he obtained 135 grains of pure water. He alſo exploded 19,500 grain meaſures of oxygen gas with 37,000 of hydrogen gas, and obtained 30 grains of water, containing in it a little nitric acid. From theſe experiments he concluded that water was a compouud.—Mr Cavendiſh muſt therefore be conſidered as the real diſcoverer of the compoſition of water. He was the firſt who aſcertained that water was produced by firing oxygen and hydrogen gas, and the firſt that drew the proper concluſion from that fact. Mr Watt, indeed, had alſo drawn the proper concluſion from the experiments of Dr Prieſtley and Mr Warltire, and had even performed a number of experiments himſelf to aſcertain the fact, before Mr Cavendiſh had communicated his; but he had been deterred from publiſhing his theory by ſome experiments of Dr Prieſtley, which appeared contrary to it †. He has therefore a claim to the merit of the diſcovery; a claim, however, which does not affect Mr Cavendiſh, who knew nothing of the theory and experiments of that ingenious philoſopher.

Meanwhile, in the winter 1781-2, Mr Lavoiſier, who had ſuſpected, that when oxygen and hydrogen gas were exploded, ſulphuric or ſulphurous acid was produced, made an experiment in order to aſcertain the fact, at which Mr Gingembre aſſiſted. They filled a bottle, capable of holding ſix pints (French), with hydrogen gas, to which they ſet fire, and then corked the bottle, after pouring into it 2 oz. (French) of lime water. Through the cork there paſſed a copper tube, by means of which a ſtream of oxygen gas was introduced to ſupport the flame. Though this experiment was repeated three times, and inſtead of lime water a weak ſolution of alkali and pure water were ſubſtituted, they could not obſerve any product whatever ‡. This reſult aſtoniſhed Mr Lavoiſier exceedingly: he reſolved, therefore, to repeat the experiment on a larger ſcale, and if poſſible with more accuracy. By means of pipes furniſhed with ſtop-cocks, he put it in his power to ſupply both gaſes as they ſhould be wanted, that he might be enabled to continue the burning as long as he thought proper.

The experiment was made by Lavoiſier and la Place on the 24th of June 1783, in the preſence of Meſſrs le Roi, Vandermonde, ſeveral other academicians, and Sir Charles Blagden, who informed them that Mr Cavendiſh had already performed it, and that he had obtained water.* They continued the inflammation till all their ſtock of gaſes was waſted, and obtained about 295 grains of water, which, after the moſt rigid examination, appeared to be perfectly pure. From this experiment Lavoiſier concluded, that water was compoſed of oxygen and hydrogen. Mr Monge ſoon after performed the ſame experiment, and obtained a ſimilar reſult: and it was ſoon after repeated again by Lavoiſier and Meuſnier on a ſcale ſufficiently large to put the fact beyond doubt.*

† *Phil. Tranſ.* lxxv. 330.

‡ *Mem. Par.* 1781, p. 470.

* *Ibid.* p. 472.

* *Ibid.* p. 474.

344
Proofs the con fition o water.

The proofs that water is a compound are of two kinds; it has been actually compoſed, and it has been decompoſed.

345
Experi- ment of Lavoiſie and Me nier.

With regard to the compoſition of water, we ſhall relate the celebrated experiment made by Lavoiſier and Meuſnier in the month of February 1785, in the preſence of a numerous deputation from the academy of ſciences, and ſo many other ſpectators, that it may be conſidered as having been performed in public. Every precaution was taken to enſure ſucceſs. The gaſes had been prepared with care, and held for ſome time over a ſolution of potaſs, in order to deprive them of any acidity which they might accidentally contain; and before entering into the glaſs globe where they were to be burnt, they were made to paſs over newly calcined potaſs, to deprive them of the water which they might happen to retain in ſolution. The hydrogen gas had been obtained by paſſing ſteam through iron at a white heat; the oxygen gas was procured from the red oxyd of mercury. The combuſtion took place in a large glaſs globe, into which the gaſes were admitted by means of tubes furniſhed with ſtop-cocks; and the moſt ingenious contrivances were employed to aſcertain exactly the quantities of each which were conſumed (Y). The whole machine is deſcribed at large by Mr Meuſnier in the Memoires of the Academy of Sciences for 1782.

The quantities of gas employed, after deducting the 432 grains of reſiduum which were not conſumed, were 2794,76 grains of oxygen gas, and 471,125 of hydrogen gas. After taking from theſe 32,25 grains, = the humidity of which the oxygen gas was deprived by the calcined potaſs, and 44,25 grains, = the weight which the hydrogen loſt by the ſame proceſs, there remains altogether 3188,4 grains of gas.

The quantity of water obtained amounted to 3219 grains; the ſpecific gravity of which was to diſtilled water as 1,0051 to 1. This quantity was 30 grains more than the gas employed. The difference, no doubt, was owing to a ſmall error in eſtimating the weight of the gaſes; which indeed it is extremely difficult to avoid, as the weight is altered by the ſmalleſt difference of temperature. This water had a ſlight ſmell, and a taſte ſenſibly acid; it reddened ſlightly blue paper, and effervesced with the carbonat of potaſs. 1152 grains of that water being ſaturated with potaſs, and evaporated to dryneſs, left 20 grains of a ſalt which melted on the fire like nitre. It follows from this experiment, that the quantity of acid contained in the whole water would not have been quite ſufficient to have formed 56 grains of nitre.

The reſiduum weighed, as has been already obſerved, 432 grains; its volume was equal to 444 grains of oxygen gas; it was diminiſhed by nitrous gas (Z) preciſely as gas would be which contained 0,24 parts of oxygen; it rendered lime water ſomewhat turbid, which indicated the preſence of carbonic acid gas.

From the compariſon of the weights, and volumes of the gaſes conſumed, it was concluded that water conſiſts

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(Y) A variety of inſtruments have been invented by the French chemiſts for that purpoſe. Theſe inſtruments they have denominated *Gazometers*.

(Z) This gas ſhall be afterwards deſcribed. It has the property of abſorbing almoſt inſtantaneouſly the oxygen gas with which it comes into contact. It is therefore often uſed, in order to diſcover how much oxygen gas exiſts in any mixture.

muſt have been owing to common air remaining in the tubes and other parts of the apparatus, in ſpite of all the precautions that were taken to prevent it; if it did not rather proceed from unavoidable errors in their valuations.

	Gr. Troy.
The quantity of azotic gas introduced was	151,178
The quantity found in the reſiduum was	170,258
There was therefore a ſurplus of - -	19,080 gr.

As ſufficient precautions had been taken to prevent the introduction of carbonic acid gas, the quantity found in the reſiduum muſt have been formed during the proceſs. There muſt therefore have been a ſmall quantity of carbon introduced. Now zinc often contains carbon, and hydrogen has the property of diſſolving carbon: probably, then, the carbon was introduced in this manner. The carbonic acid found in the reſiduum amounted to 23,306 grains, which, according to Lavoiſier's calculation, is compoſed of 8,958 grains of carbon, and 14,348 grains of oxygen.

Subſtracting theſe 8,958 grains of carbon, and the ,530 of a grain of hydrogen, which remained in the veſſel, from the total of hydrogen introduced, there will remain 852,690 grains for the hydrogen that diſappeared.

Subſtracting the 14,348 grains of oxygen which entered into the compoſition of the carbonic acid, and the reſiduum of oxygen, which amounted to 188,371 grains, the quantity of oxygen that diſappeared will amount to 5093,940 grains.

Hydrogen that diſappeared, - -	852,690 gr. troy.
Oxygen, - - - - -	5093,940
Total, -	5946,630
Quantity of water obtained, -	5943,798
Which is leſs than the gaſes conſumed by . - - -	2,832 grains*.

348
Objections to the compoſition of water examined.

Such are the principal experiments upon which the opinion is founded that water is a compound. Let us examine them, and ſee whether they are ſufficient to eſtabliſh that opinion. The circumſtances which chiefly claim our attention, and which have been chiefly inſiſted on, are theſe:

1. The whole of the gaſes was not conſumed.
2. In the reſiduum were found ſeveral ſubſtances which were not introduced, and which muſt therefore have been formed during the combuſtion.
3. The water obtained was ſeldom perfectly pure. It generally contained ſome nitric acid.
4. As only part of the gaſes were conſumed, and as all gaſes contain water in them, might not the gas which diſappeared have been employed in forming the other ſubſtances found in the reſiduum? and might not the water obtained have been merely what was formerly diſſolved in the gaſes, and which had been precipitated during the experiment?

That the whole of the gaſes was not conſumed, will not ſurpriſe us, if we recollect that it is impoſſible for that to take place, allowing them to be perfectly pure, except they be mixed in preciſely the proper proportions, and not even then, except every particle of them could be raiſed to the proper temperature. Now how can this be done in experiments of that nature?

But how is it poſſible to procure a large quantity of gas completely pure? and ſuppoſing it were poſſible, how can every particle of atmoſpheric air be excluded? In the laſt experiment, notwithſtanding every precaution, 15 cubic inches (French) were admitted; and there is reaſon to believe, from the reſults, that the quantity was even conſiderably greater than this. But if any atmoſpheric air be admitted, there muſt be a reſiduum of azotic gas.

In the firſt experiment it had been previouſly aſcertained that the oxygen gas employed contained $\frac{1}{12}$th of azotic, or about 233,05 grains; and the reſiduum contained at moſt 329,1 grains, or 96,05 grains more than what had for certain pre-exiſted in the gaſes.

In the ſecond experiment, the azot in the reſiduum, amounted at moſt to $\frac{1}{8}$th of the oxygen gas employed. But the oxygen was procured from the black oxyd of manganeſe, which always yields a quantity of azot as well as of carbonic acid. It has been aſcertained, that the azot, mixed with oxygen gas procured in that manner, often exceeds $\frac{1}{8}$th. . . . . .

In the third experiment, the azotic gas found in the reſiduum amounted to 170,258 grains; and the quantity contained in the gaſes before combuſtion amounted to 151,178 grains: the ſurplus, therefore, amounted to 1908 grains.

Now, is it not much more probable that theſe inconſiderable quantities of azot, which, in the laſt experiment amounted to no more than $\frac{1}{332}$ part by weight of the whole gas employed, pre-exiſted in the gaſes before the combuſtion began, though their extreme minuteneſs prevented them from being diſcovered, than that they were formed during the experiment? a ſuppoſition which is directly contradicted by a great number of well aſcertained facts.

As to the carbonic acid gas, which in the ſecond experiment amounted to $\frac{1}{49}$th of the gaſes employed, it was evidently derived from the manganeſe, which almoſt conſtantly contains it. And when carbonic acid is once mixed with oxygen, it is difficult to ſeparate it by means of lime water, except a large quantity be uſed, as Mr Cavendiſh has well obſerved. The reaſon is that oxygen gas has the property of diſſolving carbonic acid, as Mr Welter has remarked†. Mr le Fevre de Gineau aſcertained by experiment that 1870 cubic inches of oxygen gas which did not affect lime water, loſt between $\frac{1}{38}$th and $\frac{1}{40}$th of its weight when waſhed in *milk of lime*(B).

In a ſecond experiment, he previouſly waſhed the two gaſes in milk of lime, and the reſiduum after combuſtion contained *no* carbonic acid gas. In a third experiment he waſhed only the oxygen, and obtained products equally free from carbonic acid. It is certain, then, that the *carbonic acid* is but an accidental mixture. As to the carbonic acid of the third experiment above related, which amounted only to $\frac{1}{332}$ part of the gaſes employed, the ſource of it has been already pointed out.

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* *Ann. de Chim.* viii. 225.

† *An Chim* 91.

(B) Lime mixed with water till it is of the thickneſs of *milk*, or rather of *cream*.

ley's experiments rather confirm than deſtroy the theory of the compoſition of water. We obtain from them, however, one curious piece of information, that the preſence of copper increaſes the quantity of nitric acid formed. This curious fact, with a variety of others of a ſimilar nature, will perhaps afterwards claim our attention; but at preſent we muſt conſider another theory which this phenomenon ſuggeſted, and which was firſt propoſed, we believe, by Mr de la Metherie (E).

Had the French chemiſts, it has been ſaid, employed copper veſſels in their experiments, they would have obtained three times the quantity of nitric acid. This acid, therefore, muſt in their experiments have been decompoſed, after having been formed, for want of a baſe to combine with; and the azot which appeared in the reſiduum was owing to this decompoſition. Hydrogen and oxygen, therefore, do not form water, but azot (F). Let us examine the experiment of Mr Le Fevre by this theory, as the quantity of azot was accurately aſcertained. The nitric acid obtained amounted to 43,456 grains; three times that quantity is 130,368 grains, into which 23054 grains of gas were converted; which is impoſſible. Or even ſuppoſing that the decompoſition had been going on during the whole experiment, which is directly contrary to Dr Prieſtley's experiments, and which there is no reaſon whatever to ſuppoſe, but every reaſon againſt—ſtill the whole azot amounted only to $\frac{1}{8}$th of the quantity of gas employed, allowing this gas to have contained no azot, which was evidently not the caſe. It appears, then, that this hypotheſis, even if it could be admitted, would be totally inadequate to account for the phenomena. But if we were to examine it by Mr Seguin's experiment, its abſurdity would be ſtill more glaring. In that experiment the azotic gas amounted to only 19 grains, and the quantity of gas which diſappeared was 5946 grains: ſo that were the hypotheſis true, oxygen and hydrogen gas would conſiſt of one part of oxygen and hydrogen and 312 parts of water; a ſuppoſition ſo enormouſly abſurd, that it is impoſſible for any perſon even to advance it.

It is impoſſible, therefore, for the phenomena which attend the combuſtion of oxygen and hydrogen gas to be accounted for in any way conſiſtent with common ſenſe, except we ſuppoſe that water is formed.

349 Decompoſition of water.

But the experiments above related, concluſive as they appear, are not the only ones by which this important fact has been aſcertained. Meſſrs Van Trooſtwyk and Dieman, aſſiſted by Mr Cuthbertſon, filled a ſmall glaſs tube, $\frac{1}{8}$th of an inch in diameter and 12 inches long, with diſtilled water. One end of this tube was ſealed hermetically; but, at the ſame time, a ſmall gold wire had been paſſed through it. Another wire paſſed thro' the open end of the tube, and could be fixed at greater or ſmaller diſtances from the firſt wire. By means of theſe wires, they made a great number of electrical exploſions paſs through the water. Bubbles of air appeared at every exploſion, and collected at the top of the tube. When electric ſparks were paſſed through this air, it exploded and diſappeared almoſt completely. It muſt therefore have conſiſted of a mixture of oxygen and hydrogen gas, and this gas muſt have been formed by the decompoſition of the water: for they had taken care to deprive the water before hand of all its air, and they uſed every precaution to prevent the acceſs of atmoſpherical air; and, beſides, the quantity of gas produced did not diminiſh, but rather increaſed, by continuing to operate a number of times upon the ſame water, which could not have been the caſe had it been merely air diſſolved in water: nor would atmoſpherical air have exploded and left only a very ſmall reſiduum, not more than $\frac{1}{80}$th part. They had taken care alſo to prove that the electric ſpark did not contribute to form hydrogen gas; for on paſſing it through ſulphuric and nitric acids, the product was not hydrogen, but oxygen gas†.

† *Journ* *Phyſ.* x 369.

Theſe experiments have been ſince repeated by Dr Pearſon, aſſiſted by Mr Cuthbertſon. He produced, by means of electricity, quantities of gas from water, amounting to 56,5488 cubes of $\frac{1}{10}$th of an inch each; on nitrous gas being added to which, it ſuffered a diminution of bulk, and nitrous acid appeared to have been formed; It muſt therefore have contained oxygen gas. When oxygen gas was added to the remainder, and an electric ſpark paſſed through it, a diminution took place preciſely as when oxygen and hydrogen gas are mixed: It muſt therefore have contained hydrogen. When an electric ſpark was paſſed through the gas thus produced from water, the gas diſappeared, being no doubt converted into water*.

* *Nich ſon's J. nal*, i.

Such are the proofs by which the compound nature of water is aſcertained; and we do not believe that any phyſical fact whatever can be produced which is ſupported by more complete evidence.

But what becomes of the caloric which was previouſly combined with theſe gaſes? It paſſes through the veſſel and is loſt, and its weight is too inconſiderable to make any ſenſible variation in the quantity of the product. If we were to judge from analogy, we would conclude, that the oxygen and hydrogen, while in the ſtate of gas, are probably ſomewhat lighter than after they are condenſed into water; but the difference, if it exiſts, can ſcarcely be ſenſible.

35 Comb tion a affinit water

Water is capable of combining with a vaſt number of ſubſtances: all bodies, indeed, which are ſoluble in water form a chemical union with it.

Its affinity for other bodies is doubtleſs various, tho' we have no method of aſcertaining this difference, except

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(E) Another favourite theory of La Metherie was, that gaſes themſelves are deſtitute of gravity, and that they owe their whole weight to the water with which they are combined: that during combuſtion the water of the two gaſes is depoſited; and that the gaſes themſelves eſcape through the veſſel and are loſt. He complains bitterly that this theory had never been noticed by his antagoniſts; as if it were neceſſary to refute a hypotheſis which is not ſupported by any proof whatever, and as if it had not been proved that oxygen increaſes the weight of metals, and conſequently poſſeſſes gravity.

(F) This, as has been formerly explained, was the original opinion of Dr Prieſtley; to which, though he does not explain himſelf fully, he evidently ſtill adheres. There is then no difference between his theory and this, except what relates to the decompoſition of the nitric acid.

cept in thoſe bodies which have no affinity, or but a very ſmall affinity, for each other; and it is only in a few even of theſe that this difference can be aſcertained. If muriat of barytes be poured into lime water, the lime is precipitated, owing, no doubt, to the ſuperior affinity of the muriat for water. Several very curious inſtances of the affinity of different ſalts for water have been mentioned by Mr Quatremere Dijonval. When the ſolutions of nitrat of lime and nitrat of magneſia in water are mixed together, the nitrat of magneſia is precipitated. Muriat of magneſia is alſo precipitated by muriat of lime, and ſulphat of magneſia by ſulphat of lime: ſo that it would ſeem that the ſalts which have magneſia for their baſis, have a leſs affinity for water than thoſe whoſe baſis is lime[‡].

Water has the property of diſſolving oxygen gas. If a quantity of common air be confined for ſome time above water, the whole of the oxygen is abſorbed, and nothing but the azotic gas remains. This fact was firſt obſerved by Mr Scheele.

CHAP. II. *Of* ALCOHOL.

351 iſcovery alcohol.

WINE has been known from the earlieſt ages. The Scriptures inform us, that Noah planted a vineyard and drank wine; and the heathen writers are unanimous in aſcribing the invention of this liquor to their earlieſt kings and heroes. Beer, too, ſeems to have been diſcovered at a very remote period. It was in common uſe in Egypt in the time of Herodotus[*]. Tacitus informs us, that it was the drink of the Germans[†]. Whether the ancients had any method of procuring ardent ſpirits from theſe or any other liquors, does not appear. The Greeks and Romans ſeem to have been ignorant of ardent ſpirits altogether, at leaſt we can diſcover no traces of any ſuch liquor in their writings. But among the northern nations of Europe, intoxicating liquors were in uſe from the earlieſt ages. Whether theſe liquors reſemble the beer of the Germans, we do not know. It is certain at leaſt, that the method of procuring ardent ſpirits by diſtillation was known in the dark ages; and it is more than probable that it was practiſed in the north of Europe much earlier. They are mentioned expreſsly by Thaddæus, Villanovanus, and Lully[‡].

352 ethod of rocuring

Ardent ſpirits, ſuch as brandy, for inſtance, rum, and whiſky, conſiſt almoſt entirely of three ingredients, water, *alcohol* or *ſpirit of wine*, to which they owe their ſtrength, and a ſmall quantity of a peculiar oil, to which they owe their flavour.

The alcohol may be ſeparated from the water by the following proceſs. Into the whiſky or other ardent ſpirit a quantity of potaſs is to be put, which has juſt immediately before been expoſed for about half an hour in a crucible to a red heat, in order to deprive it of moiſture. Potaſs in this ſtate has a ſtrong attraction for water; it accordingly combines with the water of the ſpirit, and the ſolution of potaſs thus formed ſinks to the bottom of the veſſel, and the alcohol, which is lighter, ſwims over it, and may eaſily be decanted off; or, what is perhaps better, the ſolution of potaſs may be drawn off from below it by means of a ſtop-cock placed at the bottom of the veſſel. It is impoſſible to fix the quantity of potaſs which ought to be uſed, becauſe that muſt depend entirely on the ſtrength of the ſpirit; but it is of no conſequence though the potaſs employed be a little more than enough. The alcohol thus obtained contains a little potaſs diſſolved, which may be ſeparated by diſtilling it in a water bath with a very ſmall heat. The alcohol paſſes over, and leaves the potaſs behind. It is proper not to diſtil to dryneſs. This proceſs is firſt mentioned by Lully. Alcohol may be obtained in the ſame manner from wine and from beer; which liquids owe their ſtrength entirely to the quantity of that ſubſtance which they contain.

353 Its properties.

Alcohol is a tranſparent liquor, colourleſs like water, of a pleaſant ſmell, and a ſtrong penetrating agreeable taſte.

It is exceedingly fluid, and has never been frozen, though it has been expoſed to a cold ſo great that the thermometer ſtood at —69°[*].

Its ſpecific gravity when pure is about 0,800.

It is exceedingly volatile, boiling at the temperature of 176°; in which heat it aſſumes the form of an elaſtic fluid, capable of reſiſting the preſſure of the atmoſphere, but which condenſes again into alcohol when that temperature is reduced. In a vacuum it boils at 56°, and exhibits the ſame phenomena: ſo that were it not for the preſſure of the atmoſphere, alcohol would always exiſt in the form of an elaſtic fluid, as tranſparent and inviſible as common air. This ſubject was firſt examined with attention by Mr Lavoiſier[†]. The fact, however, had been known long before.

Alcohol has a ſtrong affinity for water, and is miſcible with it in all proportions. The ſpecific gravity of all the different mixtures, in every proportion, and in all the different degrees of temperature, from 32 to 100°, has been lately aſcertained with great accuracy by Sir Charles Blagden and Mr Gilpin. But as a very full account of theſe intereſting experiments has been given in the Encyclopædia in the article SPIRITUOUS *Liquors*, we do not think ourſelves at liberty to repeat it here.

354 Opinions concerning its compoſition.

If alcohol be ſet on fire, it burns all away with a blue flame, without leaving any reſiduum. Boerhaave obſerved, that when the vapour which eſcapes during this combuſtion is collected in proper veſſels, it is found to conſiſt of nothing but water. Junker had made the ſame remark: and Dr Black ſuſpected, from his own obſervations, that the quantity of water obtained, if properly collected, exceeded the weight of the alcohol conſumed. This obſervation was confirmed by Lavoiſier; who found that the water produced during the combuſtion of alcohol exceeded the alcohol conſumed by about $\frac{1}{7}$th part[*].

Different opinions were entertained by chemiſts about the nature of alcohol. Stahl thought that it was compoſed of a very light oil, united by means of an acid to a quantity of water. According to Junker, it was compoſed of phlogiſton, combined with water by means of an acid. Cartheuſer, on the other hand, affirmed, that it contained no acid, and that it was nothing elſe than pure phlogiſton and water. But theſe hypotheſes were mere aſſertions ſupported by no proof whatever. Lavoiſier was the firſt who attempted to analyſe it.

355 Lavoiſier's analyſis.

He ſet fire to a quantity of alcohol in cloſe veſſels, by means of the following apparatus: BCDE (fig. 6.) is a veſſel of marble filled with mercury. A is a ſtrong glaſs veſſel placed over it, filled with common air, and capable of containing about 15 pints (French). Into this veſſel is put the lamp R filled with alcohol, the weight of which has been exactly determined. On the wick of the lamp is put a ſmall particle of phoſphorus. The mercury is drawn up by ſuction to the height IH. This glaſs communicates by means of the pipe LK with another glaſs veſſel S filled with oxygen gas, and placed over a veſſel of water T. This communication may be ſhut up at pleaſure by means of the ſtop-cock M.

[‡] Journ. de hyſ. xvii.

[*] Lib. ii. 77.

[†] De Mo. Germ. xxiii.

[‡] Berg. 4th. t. ii. 4.

[*] At Hudſon's Bay.

[†] Journ. de Phyſ. 1785.

[*] Mem. Par. 1781. p. 493.

Things being thus diſpoſed, a crooked red hot iron wire is thruſt up through the mercury, and made to touch the phoſphorus. This inſtantly kindles the wick, and the alcohol burns. As ſoon as the flame begins to grow dim, the ſtop-cock is turned, and a communication opened between the veſſels S and A; a quantity of oxygen gas ruſhes in, and reſtores the brightneſs of the flame. By repeating this occaſionally, the alcohol may be kept burning for ſome time. It goes out, however, at laſt, notwithſtanding the admiſſion of oxygen gas.

The reſult of this experiment, which Mr Lavoiſier repeated a great number of times, was as follows:

The quantity of alcohol conſumed amounted to 76,7083 grains troy.

The oxygen gas conſumed amounted to 266,82 cubic inches, and weighed 90,506 grains troy.

The whole weight of the ſubſtances conſumed, therefore, amounted to 167,2143 grains.

After the combuſtion, there were found in the glaſs veſſel 115,41 cubic inches of carbonic acid gas, the weight of which was 78,1192 grains troy. There was likewiſe found a conſiderable quantity of water in the veſſel, but it was not poſſible to collect and weigh it. Mr Lavoiſier, however, eſtimated its weight at 89,0951 grains: as he concluded, with reaſon, that the whole of the ſubſtances employed were ſtill in the veſſel. Now the whole contents of the veſſel conſiſted of carbonic acid gas and water; therefore the carbonic acid gas and water together muſt be equal to the oxygen gas and alcohol which had been conſumed.

But 78,1192 grains of carbonic acid gas contain, according to Mr Lavoiſier's calculation†, 55,279 grains of oxygen: 90,506 grains, however, of oxygen gas had diſappeared; therefore 35,227 grains muſt have been employed in forming water.

35,227 grains of oxygen gas require, in order to form water, 6,038 grains of hydrogen gas; and the quantity of water formed by this combination is 41,265 grains. But there were found 89,095 grains of water in the glaſs veſſel; therefore 47,83 grains of water muſt have exiſted ready formed in the alcohol.

It follows from all theſe data, that the 76,7083 grains of alcohol, conſumed during the combuſtion, were compoſed of

22,840	Carbon,
6,038	Hydrogen,
47,830	Water.
76,7 *.	

Such were the conſequences which Mr Lavoiſier drew from his analyſis. He acknowledged, however, that there were two ſources of uncertainty, which rendered his concluſions not altogether to be depended upon. The firſt was, that he had no method of determining the quantity of alcohol conſumed, except by the difference of weight in the lamp before and after combuſtion; and that therefore a quantity might have evaporated without combuſtion, which, however, would be taken into the ſum of the alcohol conſumed. But this error could not have been great; for if a conſiderable quantity of alcohol had exiſted in the ſtate of vapour in the veſſel, an exploſion would certainly have taken place. The other ſource of error was, that the quantity of water was not known by actual weight, but by calculation.

356 Ingredients of alcohol. To this we may add, that Mr Lavoiſier was not warranted to conclude from his experiment, that the water found in the veſſel, which had not been formed by the oxygen gas uſed, had exiſted in the alcohol in the ſtate of water: he was intitled to conclude from his data, that the ingredients of that water exiſted in the alcohol before combuſtion; but not that they were actually combined in the ſtate of water, becauſe that combination might have taken place, and in all probability did partly take place, during the combuſtion. It follows, therefore, from Mr Lavoiſier's experiments, that alcohol, ſuppoſing he uſed it perfectly pure, which is not probable, is compoſed of

0,2988	parts carbon,
0,1840	parts hydrogen,
0,5172	parts oxygen.
1,0000	

But it gives us no information whatever of the manner in which theſe ingredients are combined. That alcohol contains oxygen, has been proved by a very ingenious ſet of experiments performed by Meſſrs Fourcroy and Vauquelin. When equal parts of alcohol and ſulphuric acid are mixed together, a quantity of caloric is diſengaged, ſufficient to elevate the temperature of the mixture to 190°. Bubbles of air are emitted, the liquor becomes turbid, aſſumes an opal colour, and at the end of a few days a deep red. When examined, the ſulphuric acid is found to have ſuffered no change; but the alcohol is decompoſed, partly converted into water and partly into ether, a ſubſtance which we ſhall deſcribe immediately. Now, it is evident that the alcohol could not have been converted into water unleſs it had contained oxygen*.

When equal parts of ſulphuric acid and alcohol are mixed together and heat applied, the mixture boils at 208°, and a liquid equal to half the weight of the alcohol comes over into the receiver. This liquid is *ether*.

357 Ether. Ether is obſcurely hinted at in ſome of the older chemical authors, but little attention was paid to it till a paper appeared in the Philoſophical Tranſactions for 1730, written by a German, who called himſelf *Frobenius* (G), containing a number of experiments on it. In this paper it firſt received the name of *ether*.

358 Its properties. Ether is limpid and colourleſs, of a very fragrant ſmell, and a hot pungent taſte. Its ſpecific gravity is 0,7394. It is exceedingly volatile, boiling in the open air at 98° and in a vacuum at —20°. Were it not therefore for the preſſure of the atmoſphere, it would always exiſt in a gaſeous ſtate. Ether unites with water in the proportion of ten parts of the latter to one of the

† *Mem. Par.* 1781.

* *Ibid.* 1784.

* *Nichol ſon's Jou nal*, i. 3

(G) The name was ſuppoſed to have been feigned.

the former.* It is exceedingly inflammable, and when kindled in the ſtate of vapour burns with rapidity, or rather explodes, if it be mixed with oxygen gas.

159
Th ry of its rma- tio

Chemiſts entertained various opinions reſpecting the nature of ether. Macquer ſuppoſed, that it was merely alcohol deprived by the acid of all its water. But it was generally believed that the acid entered partly into its compoſition. Since the nature of acids has become better known, a great number of philoſophers have ſuppoſed that ether is merely alcohol combined with a quantity of oxygen furniſhed by the acid. The real compoſition of this ſingular ſubſtance has been lately aſcertained by the experiments of Fourcroy and Vauquelin.

" A combination (ſay they) of two parts of ſulphuric acid and one part of alcohol elevates the temperature to 201°, becomes immediately of a deep red colour, which changes to black a few days afterwards, and emits a ſmell perceptibly ethereal.

" When we carefully obſerve what happens in the combination of equal parts of alcohol and concentrated ſulphuric acid expoſed to the action of caloric in a proper apparatus, the following phenomena are ſeen :

" 1. When the temperature is elevated to 208°, the fluid boils, and emits a vapour which becomes condenſed by cold into a colourleſs, light, and odorant liquor, which from its properties has received the name of *ether*. If the operation be properly conducted, no permanent gas is diſengaged until about half the alcohol has paſſed over in the form of ether. Until this period there paſſes abſolutely nothing but ether and a ſmall portion of water, without mixture of ſulphurous or of carbonic acid.

" 2. If the receiver be changed as ſoon as the ſulphurous acid manifeſts itſelf, it is obſerved that no more ether is formed, but the ſweet oil of wine, water, and acetous acid, without the diſengagement hitherto of a ſingle bubble of carbonic acid gas. When the ſulphuric acid conſtitutes about four-fifths of the maſs which remains in the retort, an inflammable gas is diſengaged, which has the ſmell of ether, and burns with a white oily flame. This is what the Dutch chemiſts have called *carbonated hydrogen gas*, or *olefiant gas*, becauſe when mixed with the oxy-muriatic acid it forms oil. At this period the temperature of the fluid contained in the retort is elevated to 230° or 234°.

" 3. When the ſweet oil of wine ceaſes to flow, if the receiver be again changed, it is found that nothing more paſſes but ſulphurous acid, water, carbonic acid gas ; and that the reſiduum in the retort is a black maſs, conſiſting for the moſt part of ſulphuric acid thickened by carbon.

" The ſeries of phenomena here expoſed will juſtify the following general inductions :

" 1. A ſmall quantity of ether is formed ſpontaneouſly and without the aſſiſtance of heat, by the combination of two parts of concentrated ſulphuric acid and one part of alcohol.

" 2. As ſoon as ether is formed, there is a production of water at the ſame time ; and while the firſt of theſe compoſitions takes place, the ſulphuric acid undergoes no change in its intimate nature.

" 3. As ſoon as the ſulphurous acid appears, no more ether is formed, or at leaſt very little ; but then there paſſes the ſweet oil of wine, together with water and acetous acid.

" 4. The ſweet oil of wine having ceaſed to come over, nothing further is obtained but the ſulphurous and carbonic acids, and at laſt ſulphur, if the diſtillation be carried to dryneſs.

" The operation of ether is therefore naturally divided into three periods : the firſt, in which a ſmall quantity of ether and water are formed without the aſſiſtance of heat ; the ſecond, in which the whole of the ether which can be obtained is diſengaged without the accompaniment of ſulphurous acid ; and the third, in which the ſweet oil of wine, the acetous acid, the ſulphurous acid, and the carbonic acid, are afforded. The three ſtages have no circumſtance common to all, but the continual formation of water, which takes place during the whole of the operation.

" The ether which is formed without the aſſiſtance of caloric, and the carbon which is ſeparated without decompoſition of the ſulphuric acid, prove that this acid acts on alcohol in a manner totally different from what has hitherto been ſuppoſed. It cannot, in fact, be affirmed, that the acid is altered by the carbon, becauſe daily experience ſhews that no ſenſible attraction takes place between theſe two bodies in the cold ; neither can it be affected by the hydrogen ; for in that caſe ſulphurous acid would have been formed, of which it is known that no trace is exhibited during this firſt period. We muſt therefore have recourſe to another ſpecies of action, namely, the powerful attraction exerciſed by the ſulphuric acid upon water. It is this which determines the union of the principles which exiſt in the alcohol, and with which the concentrated acid is in contact : but this action is very limited if the acid be ſmall in quantity ; for an equation of affinity is ſoon eſtabliſhed, the effect of which is to maintain the mixture in a ſtate of repoſe.

" Since it is proved that ether is formed in the cold by the mixture of any quantities of alcohol and ſulphuric acid, it is evident that a maſs of alcohol might be completely changed into ether and vegetable acid by uſing a ſufficient abundance of ſulphuric acid. It is equally evident that the ſulphuric acid would not by this means undergo any other change than that of being diluted with a certain quantity of water. This obſervation proves, that alcohol contains oxygen, becauſe water cannot exiſt without this principle, which muſt be afforded by the alcohol only, ſince the ſulphuric acid ſuffers no decompoſition.

" We muſt not, however, imagine, from theſe facts, that ether is alcohol minus oxygen and hydrogen. Its properties alone would contradict this ; for a quantity of carbon proportionally greater than that of the hydrogen is at the ſame time ſeparated. It may, in fact, be conceived, that the oxygen, which in this caſe combines with the hydrogen to form water, not only ſaturated that hydrogen in the alcohol, but likewiſe the carbon. So that, inſtead of conſidering ether as alcohol minus hydrogen and oxygen, we muſt, by keeping an account of the precipitated carbon and the ſmall quantity of hydrogen contained in the water which is formed, regard it as alcohol plus hydrogen and oxygen.

" The foregoing are the effects produced by a combination of alcohol and ſulphuric acid, ſpontaneouſly produced without foreign heat. Let us in the next place, obſerve, how this combination is effected when caloric is added. The phenomena are then very different, though ſome of the reſults are the ſame.

" In

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* unt de La aguais.

Alcohol.

"In the firſt place we muſt obſerve that a combination of ſulphuric acid and alcohol in equal parts does not boil at leſs than 207 degrees of temperature, while that of alcohol alone boils at 176. Now ſince ebullition does not take place till the higher temperature, it is clear that the alcohol is retained by the affinity of the ſulphuric acid, which fixes it more conſiderably. Let us alſo conſider, that organic bodies, or their immediate products, expoſed to a lively briſk heat, without the poſſibility of eſcaping ſpeedily enough from its action, ſuffer a partial or total decompoſition, according to the degree of temperature. Alcohol undergoes this laſt alteration when paſſed through an ignited tube of porcelain. By this ſudden decompoſition it is converted into water, carbonic acid and carbon. The reaſon, therefore, why alcohol is not decompoſed when it is ſubmitted alone to heat in the ordinary apparatus for diſtillation, is, that the temperature at which it riſes in vapours is not capable of effecting the ſeparation of its principles; but when it is fixed by the ſulphuric acid or any other body, the elevated temperature it undergoes, without the poſſibility of diſengagement from its combination, is ſufficient to effect a commencement of decompoſition, in which ether and water are formed, and carbon is depoſited. Nothing more therefore happens to the alcohol in theſe circumſtances than what takes place in the diſtillation of every other vegetable matter in which water, oil, acid and coal are afforded.

"Hence it may be conceived that the nature of the products of the decompoſition of alcohol muſt vary according to the different degrees of heat; and this explains why at a certain period no more ether is formed but the ſweet oil of wine and acetous acid. In fact, when the greateſt quantity of the alcohol has been changed into ether, the mixture becomes more denſe, and the heat which it acquires previous to ebullition is more conſiderable. The affinity of the acid for alcohol being increaſed, the principles of this acid become ſeparated; ſo that, on the one hand, its oxygen ſeizes the hydrogen and forms much water, which is gradually volatilized; while, on the other, the ether retaining a greater quantity of carbon, with which at that temperature it can riſe, affords the ſweet oil of wine. This laſt ought therefore to be conſidered as an ether containing an extraordinary portion of carbon, which gives it more denſity, leſs volatility, and a lemon yellow colour.

"During the formation of the ſweet oil of wine, the quantity of carbon which is precipitated is no longer in the ſame proportion as during the formation of ether.

"What we have here ſtated concerning the manner in which ether is formed by the ſimultaneous action of the ſulphuric acid and heat, appears ſo conformable to truth, that nearly the ſame effects may be produced by a cauſtic fixed alkali. In this caſe alſo a kind of ether and a ſweet oil of wine are volatilized, and coal is precipitated. It is therefore only by fixing the alcohol that the ſulphuric acid permits the caloric to operate a ſort of decompoſition. It may alſo be urged as a proof of this aſſertion, that the ſulphuric acid, which has ſerved to make ether as far as the period at which the ſweet oil of wine begins to appear, is capable of ſaturating the ſame quantity of alkali as before its mixture with the alcohol‡."

Ether may alſo be obtained by means of ſeveral other acids. The different liquids thus formed are diſtinguiſhed by prefixing the name of the acid uſed in the proceſs. Thus the ether above deſcribed is called *ſulphuric ether;* that obtained by means of nitric acid, *nitric ether,* and ſo on. There are ſeveral minute ſhades of difference between theſe various ethers, which have not yet been properly enquired into.

Alc

3 Subſ ſolub alcoh

Alcohol is capable of diſſolving a great many bodies. A conſiderable number of theſe, with the quantities ſoluble, is exhibited in the following tables.

I. *Subſtances diſſolved in large quantities.*

Names of the Subſtances.	Temperature.	240 parts of alcohol diſſolve.
Nitrat of cobalt -	54,5°	240 parts
copper -	54,5	240
alumina -	54,5	240
magneſia -	180,5	694
Muriat of zinc -	54,5	240
alumina .	54,5	240
magneſia -	180,5	1313
iron -	180,5	240
copper - -	180,5	240
Acetite of lead - -	113	
copper*		
Benzoic acid -	135,5	
Sulphat of magneſia		
Nitrat of zinc decompoſed		
iron decompoſed		
biſmuth decompoſed		

II. *Subſtances diſſolved in ſmall Quantities.*

Names of the Subſtances.	240 parts of alcohol at the boiling temperature diſſolve.
Muriat of lime - -	240 parts
Nitrat of ammonia -	214
Oxy-muriat of mercury -	212
Succinic acid - -	177
Acetite of ſoda - -	112
Nitrat of ſilver -	100
Refined ſugar - -	59
Boracic acid - -	48
Nitrat of ſoda -	23
Acetite of copper - -	18
Muriat of ammonia -	17
Arſeniat of potaſs - -	9
Acidulated oxalat of potaſs	7
Nitrat of potaſs - -	5
Muriat of potaſs - -	5
Arſeniat of ſoda - -	4
Barytes	
Strontites	
White oxyd of arſenic -	3
Tartat of potaſs - -	1
Phoſphorus	
Nitrat of lead*	
lime*	
Muriat of mercury†	
Carbonat of ammonia*	

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‡ *Nicholſon's Jour.* i. 391.

* *W.* *Phil.* lxxii

* *I* *id.*
† *M* *uer,* *ibid.*

III. *Subſtances inſoluble with Alcohol.*

Sugar of milk,
Borax,
Tartar,
Alum,
Sulphat of ammonia,
lime,
barytes*,
iron (green),
copper,
ſilver,
mercury,
zinc,
potaſs,

Sulphat of ſoda,
magneſia,
Sulphite of ſoda,
Tartrite of ſoda and potaſs,
Phoſphoric acid,
Nitrat of lead,
mercury,
Muriat of lead,
ſilver‡,
Common ſalt,
Carbonat of potaſs,
ſoda.

Theſe have been chiefly borrowed from tables which Mr de Morveau publiſhed in the *Journal de Phyſique* July 1785, and which were drawn up for the moſt part from the experiments deſcribed in Wenzel's Treatiſe on Affinities.

361 ffinities.

The affinities of alcohol are very imperfectly known. Thoſe ſtated by Bergman are as follows:

Water,
Ether,
Volatile oil,
Sulphurets of alkalies.

CHAP. III. *Of* OILS.

362 ſcovery oil.

OIL, which is of ſuch extenſive utility in the arts, was known at a very remote period. It is mentioned in Geneſis, and during the time of Abraham was even uſed in lamps*. The olive was very early cultivated, and oil extracted from it in Egypt. Cecrops brought it from Sais, a town in Lower Egypt, where it had been cultivated from time immemorial, and taught the Athenians to extract oil from it. In this manner the uſe of oil became known in Europe. But the Greeks ſeem to have been ignorant of the method of procuring light by means of lamps till after the ſiege of Troy; at leaſt Homer never mentions them, and conſtantly deſcribes his heroes as lighted by torches of wood.

Oils are divided into two claſſes, *Fixed* and *Volatile;* each of which is diſtinguiſhed by peculiar properties.

363 xed oils.

I. The FIXED OILS, called alſo *fat* or *expreſſed* oils, are numerous, and are obtained, partly from animals and partly from vegetables by ſimple expreſſion. As inſtances, we ſhall mention whale oil or train oil, obtained from the blubber of the whale; olive oil, obtained from the fruit of the olive; lintſeed oil, and almond oil, obtained from lintſeed and almond kernels. Fixed oils may alſo be obtained from poppy ſeeds, hemp ſeeds, beech maſt, and many other vegetable ſubſtances.

All theſe oils differ from each other in ſeveral particulars, but they alſo poſſeſs many particulars in common. Whether the oily principle in all the fixed oils is the ſame, and whether they owe their differences to accidental ingredients, is not yet completely aſcertained, as no proper analyſis has hitherto been made; but it is exceedingly probable, as all the oils hitherto tried have been found to yield the ſame products. In the preſent ſtate of our knowledge, it would be uſeleſs to give a particular deſcription of all the fixed oils, as the differences between them have not even been accurately aſcertained. We ſhall content ourſelves, therefore, with giving the characters which diſtinguiſh fixed oils in general, and an analyſis of one oil, by way of ſpecimen.

364 Their properties.

Fixed oils are inſoluble in alcohol, which diſtinguiſhes them from volatile oils. They are alſo inſoluble in water.

They have an unctuous feel, are tranſparent while fluid, are deſtitute of ſmell, and have a mild inſipid kind of taſte.

They are all ſuſceptible of becoming ſolid by expoſure to a ſufficient degree of cold. Olive oil and almond oil freeze at 10½ degrees‡.

They are capable of being converted into vapour by heat: but require for that purpoſe a temperature conſiderably ſuperior to that of boiling water. Olive oil boils at 600°, and moſt of the fixed oils hitherto tried require nearly the ſame degree of heat.

When in the ſtate of vapour, they take fire on the approach of an ignited body, and burn with a yellowiſh white flame. It is upon this principle that candles and lamps burn. The tallow or oil is firſt converted into the ſtate of vapour in the wick, it then takes fire, and ſupplies a ſufficient quantity of heat to convert more oil into vapour, and this proceſs goes on while any oil remains. The wick is neceſſary to preſent a ſufficiently ſmall quantity of oil at once for the heat to act upon. If the heat were ſufficiently great to keep the whole oil at the temperature of 600°, no wick would be neceſſary, as is obvious from oil catching fire ſpontaneouſly when it has been raiſed to that temperature.

365 Analyſis of olive oil.

Mr Lavoiſier analyſed olive oil, by burning it in preciſely the ſame apparatus as that which he employed for analyſing alcohol.

The quantity of oil conſumed amounted to 15,79 grains troy.

The quantity of oxygen gas amounted to 50,86 gr. troy. The whole amount therefore of the ſubſtances conſumed during the combuſtion is 66,65 grains troy.

The carbonic acid obtained amounted to 44,50 gr. There was alſo a conſiderable quantity of water, the weight of which could not be accurately aſcertained: but as the whole of the ſubſtances conſumed were converted into carbonic acid gas and water, it is evident, that if the weight of the carbonic acid be ſubtracted from the weight of theſe ſubſtances, there muſt remain preciſely the weight of the water. Mr Lavoiſier, accordingly concluded, by calculation, that the weight of the water was 22,15 grains. Now the quantity of oxygen in 44,50 grains of carbonic acid gas is 32,04 grains, and the oxygen in 22,15 grains of water is 18,82 grains: both of which taken together amount to 50,86 grains, preciſely the weight of the oxygen gas employed. There does not appear therefore to be any oxygen in olive oil.

The quantity of carbon in 44,50 grains of carbonic acid gas is 12,47 grains; and the quantity of hydrogen in 22,15 grains of water is 3,32 grains; both of which, when taken together, amount to 15,79 grains, which is the weight of the oil conſumed.

It follows, therefore, from this analyſis, that 15,79 grains of olive oil are compoſed of

12,47 Carbon,
3,32 Hydrogen.

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* ithering, l. Tranſ. ii. 336.

‡ acquer, ii.

* en. xv.

Herodot. ii. 59, d 62.

‡ Chaptal's Chemiſtry, Engliſh tranſ. iii. 43.

Olive oil therefore is compoſed of about

79 Carbon,
21 Hydrogen.

100*

* Mem. Par. 1784. and Jour. de Phyſ. for 1787, July.

In what manner theſe ſubſtances are combined, cannot be learned from this analyſis. Whether they combine directly, and ſaturate each other in that proportion, as is moſt probable—or whether the hydrogen is combined previouſly with a part of the carbon, and that compound combining with a certain quantity of carbon, forms oil, is altogether uncertain. Yet theſe queſtions are of the utmoſt importance; and till the method of ſolving them be diſcovered, we never can acquire any preciſe ideas about the conſtituent parts of a great number of ſubſtances, which, though formed ultimately of the ſame ingredients, differ very much in their properties from one another; as wax and oil; alcohol, ſugar, and ether.

366 Rancidity.

When fixed oils are expoſed to the atmoſphere, they become thick, acquire a brown colour, and a peculiarly unpleaſant ſmell: they are then ſaid to be *rancid.* When oil is poured upon water, ſo as to form a thin layer on its ſurface, and is in that manner expoſed to the atmoſphere, theſe changes are produced much ſooner, the oil becomes thicker, and aſſumes an appearance very much reſembling wax. Berthollet, who firſt examined theſe phenomena with attention, aſcribed them to the action of light: but Sennebier obſerved, that no ſuch change was produced on the oil though ever ſo long expoſed to the light, provided atmoſpherical air was excluded; but that it took place on the admiſſion of oxygen gas, whether the oil was expoſed to the light or not †. It cannot be doubted, then, that it is owing to the combination of oxygen. All ſubſtances that are capable of ſupplying that principle, the metallic oxyds, for inſtance, and ſeveral of the acids, produce the ſame effect upon oils; and it is a known fact, that oil is capable of reducing many of the metallic oxyds to the metallic ſtate, and conſequently that it has a ſtronger affinity for oxygen.

† Ann. de Chim. xi. 89.

Mr Chaptal has ſuppoſed that oils become rancid merely becauſe they contain a quantity of mucilage, with which the oxygen combines, and that when oxygen combines with fixed oils, it produces a different effect, converting them into what is called *drying oils.*

367 Drying oils.

It is certain that oils contain a quantity of mucilage; but ſome change is evidently produced on the oils themſelves by rancidity; for no agitation in water is capable of reſtoring them to their former ſtate, although water deprives them of their mucilage. *Drying oils,* ſo called becauſe they are capable of *drying* completely when ſpread out, a property which renders them uſeful in painting, ſeem, as Sennebier obſerves, to be completely deprived of mucilage; for, in order to render an oil drying, it muſt be boiled, which evaporates or decompoſes all the mucilage: they ſeem alſo to loſe part of their hydrogen ‡.

‡ Berth

36 Fixed diſſolv phur.

Fixed oils are capable of diſſolving ſulphur at their boiling temperature. The ſolution is very fetid, owing to a partial decompoſition of the oil. Hydrogen gas flies off, having a quantity of ſulphur diſſolved in it. When the ſolution cools, the ſulphur cryſtallizes.

36 And p phorus

Fixed oils diſſolve phoſphorus. The ſolution is luminous, from the ſlow combuſtion of the phoſphorus.

Fixed oils are capable of combining with many of the metallic oxyds. The compounds are called *metallic ſoaps.* Several of the oxyds are decompoſed by being boiled in oils.

Fixed oils combine alſo with the alkaline earths and with alumina. The compounds are called *earthy ſoaps.*

37 Their nities.

The affinities of the oils are as follows.

Lime,
Barytes,
Fixed alkalies,
Magneſia,
Ammonia,
Oxyd of mercury,
Other metallic oxyds (h),
Alumina.

Nitric acid,
Muriatic,
Sulphurous,
Sulphuric,
Acetous,
Sulphur,
Phoſphorus (i)

37 Volatil oils.

II. Volatile oils, called alſo *eſſential oils,* are all obtained from vegetables. They have a ſtrong aromatic ſmell, and a pungent acrid taſte. They are ſo volatile, that they may be diſtilled by the heat of boiling water. They are ſoluble in alcohol, but not in water. They evaporate on the application of heat, without leaving any ſtain behind them, which is not the caſe with the fixed oils. By this teſt, accordingly, it is eaſy to diſcover whether they have been adulterated with any of the fixed oils. Let a drop of the volatile oil fall upon a ſheet of writing paper, and then apply a gentle heat to it. If it evaporates without leaving any ſtain upon the paper, the oil is pure; but if it leaves a ſtain, it has been contaminated with ſome fixed oil or other.

Volatile oils are very numerous, and differ from one another, in fluidity and weight, in their freezing point, and in ſeveral other particulars. Little attention has been paid to the greateſt part of them, becauſe few of them have been found of any uſe. The principal quality for which they are valued is their odour. Some of them are obtained by expreſſion, as oil of bergamot, lemons, oranges; others by diſtillation, as oil of pepper-mint, thyme, lavender, &c. It would be uſeleſs, even if it were poſſible, to give a particular deſcription of all the volatile oils.

37 Their perties.

They are more inflammable than the fixed oils; a quality which they owe to their volatility. As far as experiments have hitherto been made, they ſeem to conſiſt of carbon and hydrogen; but nothing is known concerning the proportions of theſe ingredients. They thicken when expoſed to the air, probably by combining with oxygen, and form *reſins* (k).

When

(h) Their order not well aſcertained.

(i) The firſt column was aſcertained by Berthollet. The laſt is to be conſidered as unconnected with the firſt. On account of the affinity of theſe two claſſes of bodies for each other, it has not been poſſible to diſcover which of them has the greateſt affinity for oil.

(k) Reſins are concrete vegetable juices; the diſtinguiſhing property of which is inſolubility in water and ſolubility in alcohol. *Common reſin,* or *roſin,* from which they derive their name, is one of them, and ſealing wax conſiſts almoſt entirely of another.

compound, conſiſting of potaſs and carbonic acid; that lime deprived it of this acid; and that it became more active by becoming more ſimple.

376 Meyer's theory.

While Dr Black was thus occupied in Scotland, Mr Meyer was employed in Germany in the ſame reſearches; from which, however, he drew very different concluſions. His Eſſays on Lime appeared in 1764. Pouring into lime water a ſolution of potaſs (*carbonat of potaſs*), he obtained a precipitate, which he found not to differ from lime-ſtone. The alkali had therefore deprived the lime of its cauſticity and its active properties; and theſe very properties it had itſelf acquired. From which he concluded, that the cauſticity of lime was owing to a particular acid with which it had combined during its calcination. The alkali deprived the lime of this acid, and therefore had a ſtronger affinity for it. To this acid he gave the name of *acidum pingue* or *cauſticum*. It was, according to him, a ſubtile elaſtic mixt, analogous to ſulphur, approaching very nearly to the nature of fire, and actually compoſed of an acid principle and fire. It was expanſible, compreſſible, volatile, aſtringent, capable of penetrating all veſſels, and was the cauſe of cauſticity in lime, alkalies, and metals. This theory was exceedingly ingenious, and it was ſupported by a vaſt number of new and important facts. But notwithſtanding the reputation and acknowledged genius and merit of its author, it never gained many followers; becauſe the true theory of cauſticity, which had been already publiſhed by Dr Black, ſoon became known on the continent; and, notwithſtanding ſome oppoſition at firſt, ſoon carried conviction into every unprejudiced mind. Even Mr Meyer himſelf readily acknowledged its truth and importance, though he did not at firſt, on that account, give up his own theory.

When potaſs is expoſed to the action of fire, it firſt becomes ſoft, and melts into a tranſparent liquid at the commencement of ignition.

When expoſed to the air, it attracts moiſture very faſt, and is ſoon converted into a liquid. It attracts, at the ſame time, carbonic acid gas, for which it has a very ſtrong affinity. It is impoſſible, then, to keep potaſs in a ſtate of purity, except in very cloſe veſſels.

377 Sulphuret of potaſs.

It unites readily with ſulphur, and forms *ſulphuret of potaſs*. This compound may be formed two ways; either by melting the ingredients together, or by boiling them in water, and then filtrating the ſolution. Sulphuret of potaſs when dry, in which ſtate it is obtained by the firſt proceſs, is of a brown colour. It is ſoluble in water, and very ſoon attracts moiſture.

While dry it produces no change upon the air of the atmoſphere, as Meſſrs Dieman, Van Trooſtwyck, Nieuwland, and Bondt, aſcertained by experiment*. But when moiſtened with water, it very ſoon abſorbs all the oxygen gas which happens to be in the veſſel in which it is incloſed, and leaves nothing but azotic gas. This fact was firſt obſerved by Scheele, and induced him to uſe ſulphuret of potaſs for an *eudiometer*, or inſtrument to meaſure the quantity of oxygen contained in any given portion of atmoſpheric air.

If ſulphuret of potaſs be allowed to remain moiſt, and in contact with the atmoſphere, it is gradually converted into ſulphat of potaſs by the ſulphur combining with oxygen, and forming ſulphuric acid. At the ſame time the ſulphuret emits a fetid ſmell, which is known to be the odour of ſulphurated hydrogen gas. The ſulphuret then decompoſes the water with which it is mixed. Very little ſulphurated hydrogen gas, however, is emitted, except an acid (the ſulphuric, for inſtance) be poured upon the mixture, and then it is given out very copiouſly. The reaſon of this is, that there is an affinity between the potaſs and this gas. Accordingly it is retained by the potaſs after it is formed. But as the acids have a much ſtronger affinity for potaſs, as ſoon as any of them is poured in, the gas is obliged to ſeparate‡.

If liquid ſulphuret of potaſs be kept in cloſe veſſels, it is not decompoſed except in part; becauſe as ſoon as the alkali is ſaturated with the ſulphurated hydrogen gas, the action of the ſulphur on the water is at an end*. The explanation of the action of this ſulphuret on the atmoſphere, which the Dutch chemiſts above-mentioned give from theſe data, is as follows:

Sulphuret of potaſs decompoſes water; ſulphurated hydrogen gas is formed, and abſorbed by the alkali. This gas has a ſtrong affinity for oxygen, which it abſorbs from the atmoſphere: the hydrogen combines with this oxygen, and forms water; and the ſulphur is again precipitated, or rather left combined with the potaſs. Water is again decompoſed by the attraction of the ſulphur for oxygen; new ſulphurated hydrogen gas is again formed; again abſorbed; again attracts oxygen gas; and is again decompoſed. And this proceſs goes on till the whole of the ſulphur has combined with oxygen, and conſequently till the ſulphuret is converted into a ſulphat†.—The only part of this theory which requires confirmation is the action of ſulphurated hydrogen gas on oxygen gas, and the conſequent formation of water. And this they have rendered not improbable, by ſhewing that ſulphurated hydrogen gas combined with alkali has the property of abſorbing oxygen gas from the atmoſphere‡.

378 Phoſph t of pota

Potaſs unites with phoſphorus by fuſion, and forms a phoſphuret of potaſs. Little is known concerning its properties, except that it produces phoſphurated hydrogen gas.

Potaſs ſeems alſo capable of combining with carbon.

Potaſs does not combine with the metals; but it unites with many of their oxyds.

When a ſolution of potaſs is boiled upon ſilica recently procured, it diſſolves part of it. As the ſolution cools, it aſſumes the appearance of a jelly, even though previouſly diluted with 17 times its own weight of water*.

37 Gla

When equal parts of ſilica and potaſs are melted together, they combine and form *glaſs*. A ſubſtance which, whether we conſider its hardneſs, beauty, and tranſparency, its amazing ductility while hot, or the difficulty of decompoſing it, muſt be allowed to be one of the moſt uſeful compounds ever invented by man.

When the quantity of potaſs is double or triple that of the ſilica, the glaſs is ſoluble in water, and forms what is called *liquor ſilicum*.

Potaſs ſeems alſo capable of combining in the ſame manner with barytes, lime, magneſia, and alumina; but theſe combinations have never been examined with attention. Lime, however, is often added to the materials for making glaſs, and is ſuppoſed to increaſe its hardneſs and ſolidity.

The metallic oxyds have the property of rendering glaſs more fuſible, and of communicating various colours to it; they accordingly very often make a part of its compoſition. The colours communicated by theſe oxyds will appear from the following table:

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* *Ann. de Chim.* xiv. 294.

‡ *Ibid.*

* *Ibid.*

† *Ibid.*

‡ *Ibid.* p. 305.

* *Bergm.* ii. 32.

Metallic Oxyds.	Colour communicated to Glaſs.
Oxyd of gold and tin,	Purple.
Silver,	Yellow or golden.
Iron,	Pale green.
Lead,	Colourleſs.
Zinc,	White.
Antimony,	Green (N).
Arſenic,	White.
Cobalt,	Blue.
Nickel,	Blue (O)
Manganeſe,	Red.
Tungſten,	Colourleſs.
Molybdenum,	Colourleſs.
Uranium,	Grey (opake).
Titanium,	White (opake).
Tellurium,	White.
Chromum,	Green.

380 Soap. Potaſs combines readily with fixed oils, and forms the compound known by the name of *ſoap*.

381 taſs, ether a npound. Potaſs has never yet been decompoſed. Several chemiſts, indeed, have conjectured, that it was a compound of lime and azot; and ſome perſons have even endeavoured to prove this by experiment; but none of their proofs are at all ſatisfactory. We ought, therefore, in ſtrict propriety, to have aſſigned it a place in the firſt part of this article: but this would have ſeparated the alkalies from each other, and would have introduced a confuſion into the article, which would have more than counterbalanced the logical exactneſs of the arrangement. Beſides, we are certain, from a variety of facts, that all the alkalies are compounds: One of them has actually been decompounded; and the other two have been detected in the act of formation, though the ingredients which compoſe them have not hitherto been diſcovered.

Whether potaſs contains lime is a different queſtion. Were we to judge from analogy, we ſhould ſuppoſe, that the four alkaline earths, and the three alkalies, poſſeſs one common principle. They have a great number of common properties, and perhaps ought to be claſſed altogether under the name of *alkalies*.

That azot enters into the compoſition of all theſe bodies, as Fourcroy has conjectured, is far from improbable. One alkali, as we ſhall ſoon ſee, actually contains azot. But no concluſion can be drawn till future diſcoveries have lifted off the veil which at preſent obſtructs our view.

382 affinities. The affinities of potaſs are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Phoſphoric,
Oxalic,
Tartarous,
Arſenic,
Succinic,
Citric,
Formic,
Lactic,
Benzoic,
Sulphurous,
Acetous,
Saccholactic,
Boracic,
Nitrous,
Carbonic,
Pruſſic,
Oil,
Sulphur,
Phoſphorus,
Water.

The place of the metallic oxyds has not yet been aſcertained.

SECT. II. *Of Soda.*

SODA, called *mineral alkali*, becauſe it is found in the earth, was known to the ancients under the names of νιτρον and *nitrum* (P). It was long confounded with potaſs: and perhaps was never properly diſtinguiſhed from it till Du Hamel publiſhed a paper on the ſubject in 1736.

383 Properties of ſoda. Its properties, while pure, are preciſely the ſame with thoſe of potaſs, excepting only that its affinity for other bodies is not ſo ſtrong; it does not, therefore, require any particular deſcription. We ought to mention, however, that it differs from potaſs in one particular; potaſs attracts moiſture in the air, but ſoda parts with it, and when expoſed to the atmoſphere, ſoon crumbles down into a dry powder.

It is capable of combining with all the ſubſtances with which potaſs unites; but it forms compounds poſſeſſed, in general, of very different properties from thoſe of the compounds into which potaſs enters.

It is reckoned more proper than potaſs for forming glaſs and ſoap.

Some chemiſts have ſuppoſed that it is compoſed of magneſia and azot; but their proofs are inſufficient.

The order of its affinities is the ſame with that of potaſs.

SECT. III. *Of Ammonia.*

384 Diſcovery of ammonia. AMMONIA (Q), volatile alkali, or *hartſhorn*, as it is called in commerce, is mentioned as early as the 15th century. Both Baſil Valentine and Raymond Lully deſcribed the methods of procuring it. Dr Black was the firſt who diſtinguiſhed pure ammonia from the carbonat of ammonia, or ammonia combined with carbonic acid; and Dr Prieſtley firſt diſcovered the method of obtaining it in a ſtate of complete purity.

To obtain pure ammonia, mix common ſal ammoniac with three parts of ſlacked lime; apply heat; and receive

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(N) If the glaſs be made with ſoda.

(O) But reddiſh if the glaſs be formed of ſoda. *Klaproth.*

(P) The νιτρον of the Athenians was evidently the ſame ſubſtance; and ſo was the נתר of the Hebrews.

(Q) We have adopted this word, which is Dr Black's, becauſe we think it preferable to *ammoniac* or *ammoniaca*, the words propoſed and uſed by the French chemiſts.

390 Theories about the acid principle.

ciple in nature which communicated taſte and ſolubility to the bodies in which it was combined. Beccher embraced the ſame opinion; and added to it, that this acid principle was a compound of earth and water, which he conſidered as two elements. Stahl adopted the theory of Beccher, and endeavoured to prove, that his acid principle was ſulphuric acid; of which, according to him, all the other acids were mere compounds. But his proofs were only conjectures or vague experiments, from which nothing could be deduced. Nevertheleſs, his opinion, like every other which he advanced in chemiſtry, continued to have ſupporters for a long time, and was even countenanced by Macquer. At laſt its defects began to be perceived, Bergman and Scheele declared openly againſt it; and their diſcoveries, together with thoſe of the French chemiſts, notwithſtanding the ill-natured attempts of Monnet to ſupport it, demonſtrated the falſehood of both parts of the theory, by ſhewing that ſulphuric acid did not exiſt in the other acids, and that it was not compoſed of water and earth, but of ſulphur and oxygen.

391 Lavoiſier's theory.

The opinion however, that acidity is owing to ſome principle common to all the ſalts, was not abandoned. Wallerius, Meyer and Sage, had advanced different theories in ſucceſſion about the nature of this principle; but as they were founded rather on conjecture and analogy than direct proof, they obtained but few advocates. At laſt Mr Lavoiſier, by a number of ingenious and accurate experiments, proved, that ſeveral combuſtible ſubſtances when united with oxygen, form acids; that a great number of acids contain oxygen; and that when this principle is ſeparated from them, they loſe their acid properties. He concluded, therefore, that the acidifying principle is oxygen, and that acids are nothing elſe but combuſtible ſubſtances combined with oxygen, and differing from one another, according to the nature of the combuſtible baſe. This concluſion has been confirmed by every ſubſequent obſervation. All the acids hitherto analyſed contain oxygen, *one*, perhaps excepted, *the Pruſſic acid*, which poſſeſſes properties ſo different from the reſt, that it might, without great impropriety, be placed in a diſtinct claſs. It is probable, therefore, that thoſe acids which it has not yet been poſſible to decompoſe conſiſt of oxygen combined with a combuſtible baſe: but till this analyſis has actually been accompliſhed, the theory of Mr Lavoiſier cannot be conſidered as completely demonſtrated (R).

392 List of the acids.

The acids at preſent known amount to about 39, moſt of which have been examined within theſe 30 years. Their names are as follows:

1. Sulphuric acid,
2. Sulphurous,
3. Nitric,
4. Nitrous,
5. Muriatic,
6. Oxy-muriatic,
7. Phoſphoric,
8. Phoſphorous,
9. Boracic,
10. Fluoric,
11. Carbonic,
12. Acetic,
13. Acetous,
14. Oxalic,
15. Tartarous,
16. Citric,
17. Malic,
18. Lactic,
19. Saccholactic,
20. Gallic,
21. Benzoic,
22. Succinic,
23. Camphoric,
24. Suberic,
25. Laccic,
26. Pyromucous,
27. Pyrolygnous,
28. Pyrotarous,
29. Pruſſic,
30. Formic,
31. Sebacic,
32. Bombic,
33. Zoonic,
34. Arſenic,
35. Tungſtic,
36. Molybdic,
37. Chromic,
38. Platinic,
39. Stannic,

Theſe acids ſhall form the ſubject of the following ſections.

Sect. I. *Of Sulphuric Acid.*

Sulphur combines with two different quantities of oxygen: with the ſmaller quantity it forms *ſulphurous acid;* with the larger, *ſulphuric acid.* The laſt of theſe is the ſubject of the preſent ſection.

393 Diſcovery of ſulphuric acid.

The ancients were acquainted with ſome of the compounds into which ſulphuric acid enters; *alum*, for inſtance, and *green vitriol:* but they appear to have been ignorant of the acid itſelf. It is firſt mentioned in the works of Baſil Valentine, which were publiſhed about the end of the 15th century.

It was for a long time obtained by diſtilling *green vitriol*, a ſalt compoſed of ſulphuric acid, and green oxyd of iron; hence it was called *oil of vitriol*, and afterwards *vitriolic acid.* Another method of obtaining it was by burning ſulphur under a glaſs bell; hence it was called alſo *oleum ſulphuris per campanam.* The French chemiſts, in 1787, when they formed a new chemical nomenclature, gave it the name of *ſulphuric acid.*

394 Method of procuring it.

At preſent it is generally procured by burning a mixture of ſulphur and nitre in chambers lined with lead. The theory of this proceſs requires no explanation. The nitre ſupplies a quantity of oxygen to the ſulphur, and the air of the atmoſphere furniſhes the reſt. The acid thus obtained is not quite pure, containing a little potaſs, ſome lead, and perhaps alſo nitric and ſulphurous acids. Theſe acids may be driven off by applying for ſome time a gentle heat, and afterwards the ſulphuric acid itſelf may be diſtilled over pure.

395 Its component parts.

It appears from an experiment of Mr Berthollet, that ſulphuric acid contains 63,2 parts of ſulphur, and 36,8 of oxygen. He aſcertained, in the firſt place*, that nitre is totally decompoſed by being heated with ¼th of ſulphur. He then mixed together 288 grains of nitre, and 72 of ſulphur; and after expoſing them to a ſufficient heat, he found 12 grains of ſulphur ſublimed, and 228 grains of ſulphat of potaſs†. But the ſum of the ingredients was 360 grains; conſequently 120 grains had been diſſipated. All this loſs muſt have been ſuffered by the acid of the nitre, for the heat was too ſmall to ſeparate any of the alkali. According to Mr Kirwan 288 grains of nitre contain 132,96 of alkali,

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(R) This theory has been carried ſo far by ſome chemiſts, that they have conſidered it as a concluſive proof, that oxygen did not enter into the compoſition of a body, if they could ſhew that the body was not an acid. Thus, according to them, *water* cannot contain oxygen, becauſe water is not an *acid.*—But ſurely no theory, however ingenious and ſatisfactory, can for a moment be put in competition with experiment. The ways of Nature are not as our ways, nor her thoughts as our thoughts.

* *Mem. Par.* 1781. 232.

† *Mem. Par.* 1782. 603.

kali, and 155,04 of acid. 155,04—120 = 35,04 = quantity of oxygen furniſhed by the nitre to convert 60 grains of ſulphur into acid.

396
Its properties.

Sulphuric acid is a liquid, ſomewhat of an oily conſiſtence, tranſparent and colourleſs as water, without any ſmell, and of a very ſtrong acid taſte. When applied to animal or vegetable ſubſtances, it very ſoon deſtroys their texture.

It always contains a quantity of water; part of which, however, may be driven off by the application of a moderate heat. This is called *concentrating the acid.* When as much concentrated as poſſible, its ſpecific gravity is 2,000.

It changes all vegetable blues to a red, except indigo.

According to Erxleben, it boils at 546°; according to Bergman, at 572°.

397
Its cryſtals.

When expoſed to a ſufficient degree of cold it cryſtallizes or freezes; and after this has once taken place, it freezes again by the application of a much inferior cold. Morveau froze it at —4°; it aſſumed the appearance of frozen ſnow. After the proceſs began it went on in a cold not nearly ſo intenſe. The acid melted ſlowly at 27,5°; but it froze again at the ſame temperature, and took five days to melt in the temperature of 43° ‡. Chaptal, who manufactured this acid, once obſerved a large glaſs veſſel full of it cryſtallized at the temperature of 48°. Theſe cryſtals were in groups, and conſiſted of flat hexahedral priſms, terminated by a ſix-ſided pyramid. They felt hotter than the ſurrounding bodies, and melted on being handled.*. Chaptal has obſerved, that ſulphuric acid, in order to cryſtallize, muſt not be too concentrated. This obſervation has been extended a good deal further by Mr Keir. He found, that ſulphuric acid, of the ſpecific gravity of 1,780, froze at 45°; but if it was either much more or much leſs concentrated, it required a much greater cold for congelation †.

‡ *Encycl. Method. Chim.* i. 376.

* *Journ. de Phyſ.* xxxi. 473.

† *Phil. Tranſ.* lxxvii. Part ii.

398
Its affinity for water.

Sulphuric acid has a very ſtrong attraction for water, Neumann found, that when expoſed to the atmoſphere it attracted 6,25 times its own weight. Mr Gould found, that 180 grains of acid, when expoſed to the atmoſphere, attracted 68 grains of water the firſt day, 58 the ſecond, 39 the third, 23 the fourth, 18 the fifth, and at laſt only 5, 4, 3, 4, 3, &c. The 28th day the augmentation was only half a grain.* The affinity therefore between ſulphuric acid and water, as is the caſe in general with other ſubſtances, becomes weaker the nearer they approach to ſaturation. He does not ſpecify the ſpecific gravity of his acid; but as it only attracted 3,166 times its own weight, it could not have been very concentrated.

* *Phil. Tranſ.* 1684.

When ſulphuric acid is mixed with water, a great quantity of caloric is evolved. A mixture of equal parts of theſe liquids cauſes a heat almoſt equal to that of boiling water. Lavoiſier and De la Place found, that when 2,625 lbs troy of ſulphuric acid, of the ſpecific gravity 1,87058, was mixed with 1,969 lbs. troy of water, as much caloric was evolved as melted 4,1226 pounds troy of ice, or as much caloric as the acid and water would have given out had they been heated without mixture to 155,9° †. This caloric is owing chiefly, if not ſolely, to the increaſe of denſity in the water; for when equal quantities of ſulphuric acid and water are mixed together, the ſpecific gravity is much greater than the mean; and it has been formerly ſhewn, that whenever bodies become denſer they give out caloric.

† *Mem Par.* 1

399
Strengt ſulphur acid of rious d ſities.

Since there is ſuch a ſtrong affinity between ſulphuric acid and water, and ſince the denſity of the mixture is different from the mean denſity of the ingredients, it becomes a problem of the greateſt importance to determine how much of the ſtrongeſt ſulphuric acid that can be prepared exiſts in any given quantity of ſulphuric acid of inferior ſpecific gravity, and which conſequently conſiſts of a determinate quantity of this ſtrong acid diluted with water.

This problem has been ſolved by Mr Kirwan ‡. He took ſulphuric acid of the ſpecific gravity 2,000, which is the ſtrongeſt that can be procured, for his ſtandard, and the point was to determine how much of this ſtandard acid exiſted in a given quantity of acid of inferior denſity.

‡ *Iriſh Tranſ.*

He concluded, from a number of experiments with ſulphuric acid, of the ſpecific gravities 1,8846, 1,8689, 1,8042, 1;7500 (for he could not procure an acid of the ſpecific gravity 2,000 at the temperature of 60°, in which his experiments were performed), that when equal parts of ſtandard acid and water are mixed, the denſity is increaſed by $\frac{1}{75}$th part of the whole mixture. Then, by applying a formula given by Mr Poujet (s), he calculated, that the increaſe of denſity, on mixing different

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(s) Mr Poujet undertook the examination of the ſpecific gravity of alcohol mixed with different quantities of water. He took for his ſtandard alcohol whoſe ſpecific gravity was 0,8199, at the temperature of 65,75°. He then formed ten mixtures; the firſt containing nine meaſures of alcohol and one of water, the ſecond eight meaſures of alcohol and two of water, and ſo on till the laſt contained only one meaſure of alcohol and nine of water. He took care that each of theſe meaſures ſhould contain equal bulks, which he aſcertained by weight, obſerving that a meaſure of water was to a meaſure of alcohol as 1 to 0,8199. Thus 10000 grains of water and 8199 of alcohol formed a mixture containing equal bulks of each. From the ſpecific gravity of each of theſe mixtures he diſcovered how much they had diminiſhed in bulk in conſequence of mixture, by the following method.

Calling A the real ſpecific gravity of any of the mixtures; B its ſpecific gravity found by calculation, ſuppoſing no diminution of bulk; n the number of meaſures compoſing the whole maſs; $n - x$ the number to which it is reduced in conſequence of mutual penetration—it is evident, ſince the increaſe of denſity does not diminiſh the weight of the whole maſs, that $n B = \overline{n - x} \times A$. Therefore $x = \frac{A - B}{A} \times n$, or (making $n = 1$) = $\frac{A - B}{A}$. $\frac{A - B}{A}$ is therefore the diminution of volume produced by the mixture.

The

lphuric Acid.

different quantities of ſtandard acid and water, was as in the following table :

Number of parts of water.	Number of parts of ſtandard acid.	Augmentation of denſity.
5	95	0,0252
10	90	0,0479
15	85	0,0679
20	80	0,0856
25	75	0,0699
30	70	0,1119
35	65	0,1213
40	60	0,1279
45	55	0,1319
50	50	0,1333

The firſt 50 numbers of the following table were formed by adding theſe augmentations to the ſpecific gravity of the above mixture found by calculation, and taking the arithmetical mean for the intermediate quantities. The remaining numbers were formed from actual obſervation. He found by the firſt part of the table, that 100 parts of acid, of the ſpecific gravity 1,8472, contained 88,5 parts ſtandard, conſequently 400 grains of this acid contain 354 grains ſtandard. He took ſix portions of this acid, each containing 400 grains, and added to them as much water as made them contain reſpectively 48, 46, 44, 42, 40, 38 grains ſtandard. The quantity of water to be added in order to produce this effect, he found by the following method. Suppoſe $x =$ the quantity of water to be added to 400 parts of acid, that the mixture may contain 48 *per cent*, of ſtandard acid. Then $400 + x : 354 :: 100 : 48$, and conſequently $x = 337,5$. After finding the ſpecific gravity of theſe, the half of each was taken out, and as much water added ; and thus the ſpecific gravities, correſponding to 24, 23, 22, 21, 20, 19, were found. Then ſix more portions, of 400 grains each, were taken, of the ſpecific gravity 1,8393, and the proper quantity of water added to make them contain 36, 34, 32, 30, 28, 26 *per cent.* of ſtandard. Their ſpecific gravities were found, the half of them taken out, and as much water added ; and thus the ſpecific gravity of 18, 17, 16, 15, 14, and 13 found. Care was taken, after every addition of water, to allow the ingredient ſufficient time to unite.

Sulphuric Acid.

The laſt 11 numbers were only found by analogy ; obſerving the ſeries of decrement of the four laſt numbers before them.

TABLE

The following table contains the reſult of Mr Poujet's experiments, calculated according to that formula ; the whole volume or n being $= 1$.

Meaſures of Water.	Meaſures of Alcohol.	Diminution of the whole volume = 1 by experiment.	By calculation.
1	9	0,0109	0,0103
2	8	0,0187	0,0184
3	7	0,0242	0,0242
4	6	0,0268	0,0276
5	5	0,0288	
6	4	0,0266	0,0276
7	3	0,0207	0,0242
8	2	0,0123	0,0184
9	1	0,0044	0,0103

It is evident, from this table, that the diminution of the bulk of the mixture follows a regular progreſſion. It is greateſt when the meaſures of water and alcohol are equal, and diminiſhes as it approaches both ends of the ſeries. Mr Poujet accounts for this by conceiving the alcohol to be diſſolved in the water, which retains a part of it in its pores, or abſorbs it. The quantity abſorbed ought to be in the ratio of that of the ſolvent and of the body diſſolved, and each meaſure of water will retain a quantity of alcohol proportional to the number of meaſures of alcohol in the mixture. Thus in a mixture formed of nine meaſures of alcohol and one of water, the water will contain a quantity of alcohol $= 9$; in one of eight meaſures of alcohol and two of water, the water will contain a quantity of alcohol $= 8$. Therefore the diminution of bulk in each mixture is in a ratio compounded of the meaſures of alcohol and water which form it ; in the above table, as 1×9, 2×8, 3×7, 4×6, &c. And in general, taking the diminution of bulk when the meaſures of both liquids are equal for a conſtant quantity, and calling it, c, calling the number of meaſures n, the number of meaſures of alcohol x, the increaſe of denſity grains of pure carbonat of potaſs, dried in a red heat, in diſtilled water. The whole weighed 4570 grains. He took 360 grains of this mixture, which contained 120 grains of carbonat of potaſs, and ſaturated it with pure ſulphuric acid of the ſpecific gravity 1,565, which, according to the above table, contained 61 *per cent.* of ſtandard acid. The acid required for ſaturating the ſolution of potaſs amounted to 130 grains, and contained therefore 79 of ſtandard. The carbonic acid diſengaged was 34 grains, and conſequently the quantity of alkali was 120 — 34 = 86 grains. The ſolution being turbid, was diluted with 3238 grains of water. Its ſpecific gravity was then 1,013 at the temperature of 60°. The weight of the whole was 3694 grains. Forty-five grains of ſulphat of potaſs (potaſs combined with ſulphuric acid) diſſolved in 1017 grains of diſtilled water, have the ſame ſpecific gravity at the ſame temperature; from whence it follows, that the proportion of ſalt in each was equal. But in the laſt ſolution the quantity of ſalt was $\frac{1}{23,6}$ of the whole; therefore the quantity of ſalt in the firſt was $\frac{3694}{23,6} = 159,52$ grs. Now of this weight 86 grains were alkali; the remainder, therefore, which amounts to 70,52 grains, muſt be acid. But the quantity of ſtandard acid employed was 79 grains; of this there were $8\frac{1}{2}$ grains, which did not enter into the combination, and which muſt have been pure water: 79 parts of ſtandard acid, therefore, contain at leaſt 8,5 parts of water, and conſequently 100 parts of ſtandard acid contain 10,75 parts of water. It only remains now to conſider how much water ſulphat of potaſs contains. Mr Kirwan thinks it contains none, becauſe it loſes no weight in any degree of heat below ignition, and even when expoſed to a red heat for half an hour it hardly loſes a grain. This is certainly ſufficient to prove, at leaſt, that it contains very little water; and conſequently we may conclude, with Mr Kirwan, that 100 parts of ſulphuric acid, of the ſpecific gravity 2,000, are compoſed pretty nearly of 89,25 of pure acid and 10,75 of water. This method uſed by Mr Kirwan is nearly the ſame with that propoſed by Mr Keir*.

It ſeems even poſſible to obtain ſulphuric acid free from all the water that may not be neceſſary to its acid ſtate. When it is procured by diſtillation from green vitriol, if the receiver be changed after the proceſs has gone on for ſome time, a quantity of acid is obtained in a ſolid form, or cryſtallized. This, as Morveau has ſhewn, is ſulphuric acid deprived of the water with which it is uſually combined. When this *glacial* acid, as it has been called, is expoſed to the air, it riſes in white fumes, and is ſoon diſſipated. This ſingular effect is produced by its violent attraction for the water which exiſts in atmoſpheric air. When thrown into water, it ſeizes it with violence; a great deal of caloric is evolved, ſufficient, if the quantity of water be not too great, to elevate the whole in vapours†.

401
Action of this Acid on other bodies.

Sulphuric acid is capable of decompoſing alcohol and oils; and when aſſiſted by heat, it decompoſes alſo ſome of the metallic oxyds which contain the greateſt quantity of oxygen; as red oxyd of lead, black oxyd of mangaueſe. It decompoſes likewiſe all the ſulphurets and phoſphurets which have an alkaline or earthy baſis.

It oxydates iron, zinc, and mangaueſe, in the cold. By the aſſiſtance of heat it oxydates ſilver, mercury, copper, antimony, biſmuth, arſenic, tin, and tellurium. At a boiling heat it oxydates lead, cobalt, nickel, molybdenum. It does not act upon gold, platinum, tungſten, nor titanium.

It unites readily with all the alkalies, the alkaline earths, alumina, and jargonia, and with moſt of the metallic oxyds, and forms ſalts denominated *ſulphats*. Thus the combination of ſulphuric acid and ſoda is called *ſulphat of ſoda*; the compound of ſulphuric acid and lime, *ſulphat of lime*, and ſo on. It does not act upon ſilica nor adamanta:

402
Its affinities.

The affinities of ſulphuric acid are as follows ‡:

Barytes,
Strontites*,
Potaſs,
Soda,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia †?
Oxyd of zinc,
——— iron,
——— manganeſe,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— biſmuth,

Oxyd

Sulphurous Acid.

* ir's *Dictionary*, *t Acid.*

† *Encycl. Method. Chim.* i. 590.

‡ See *Bergman* and *Lavoiſier*.

* *Dr Hope, Tranſ. Edin.* iv.

† *Vauquelin, Ann. de Chim.* xxii. 208.

Then ſince the increaſe of denſity does not change the weight of the whole, $\overline{1-x} \times a + b\,x = \overline{1-4cx+4cx^2} \times y$.

$$\text{Hence } x = 0,5 - \frac{a-b}{8cy} + \sqrt{\frac{a-y}{4cy} + \left(\frac{a-b}{8cy} - 0,5\right)}$$

$$y = \frac{a - ax + bx}{1 - 4cx + 4cx^2}$$

And making $a = 1$, $b = 0,8199$, $c = 0,0288$

$$x = 0,5 - \frac{0,1801}{0,2304y} + \sqrt{\frac{1-y}{0,1152y} + \left(\frac{0,1801}{0,2304y} - 0,5\right)}$$

$$y = \frac{1 - 0,1801x}{1 - 0,1152x + 0,1152x^2}.$$ See *Iriſh Tranſ.* III.

Nitric Acid.

Jargonia* ?
Metallic oxyds,
Water.

* auquelin, A. de Cn. xxii. 2.

SECT. III. *Of Nitric Acid.*

THERE are three different ſubſtances compoſed of azot and oxygen, *nitric acid*, *nitrous acid*, and *nitrous gas*. The firſt contains moſt oxygen, the laſt contains leaſt.

409 covery nitric al.

Nitric acid ſeems to have been firſt obtained in a ſeparate ſtate by Raymond Lully, who was born at Majorca in 1235. He procured it by diſtilling a mixture of nitre and clay. Baſil Valentine, who lived in the 15th century, deſcribes the proceſs minutely, and calls the acid *water of nitre*. It was afterwards denominated *aqua fortis*, and *ſpirit of nitre*. The name *nitric acid* was firſt given it in 1787 by the French chemiſts.

410 thod of curing

Nitric acid is generally obtained in large manufactories by diſtilling a mixture of nitre (T) and clay; but the acid procured by this proceſs is weak and impure. Chemiſts generally prepare it by diſtilling three parts of nitre and one of ſulphuric acid in a glaſs retort. This method was firſt uſed by Glauber. When obtained in this manner it contains ſome nitrous acid which may be expelled by the application of a very gentle heat§.

§ cheele.

Nitric acid is one of the moſt important inſtruments of analyſis which the chemiſt poſſeſſes; nor is it of inferior conſequence when conſidered in a political or commercial view, as it forms one of the moſt eſſential ingredients of gunpowder. Its nature and compoſition accordingly have long occupied the attention of philoſophers. We ſhall endeavour to trace the various ſteps by which its component parts were diſcovered.

411 covery its component ts.

As nitre is often produced upon the ſurface of the earth, and never except in places which have a communication with atmoſpheric air, it was natural to ſuppoſe that air, or ſome part of the air, entered into the compoſition of nitric acid. Mayow having obſerved, that nitre and atmoſpherical air were both poſſeſſed of the property of giving a red colour to the blood, and that air was deprived of this property by combuſtion, and reſpiration—concluded that nitre *contained that part of the air which ſupported combuſtion, and was neceſſary for reſpiration.*

Dr Hales, by applying heat to nitric acid, and what he called *Walton mineral*, obtained a quantity of air poſſeſſed of ſingular properties. When atmoſpherical air was let into the jar which contained it, a reddiſh turbid fume appeared, a quantity of air was abſorbed, and the remainder became tranſparent again*. Dr Prieſtley diſcovered that this air could only be obtained from nitric (U) acid; and therefore called it *nitrous air*. He found, that when this gas was mixed with oxygen gas, nitrous acid was reproduced. Here, then, we find, that oxygen is a part of the nitric acid, and conſequently that Mayow's affirmation is verified.

* Veget. tics, 284.

Dr Prieſtley, however, explained this fact in a different manner. According to him, nitrous gas is compoſed of nitrous acid and phlogiſton. When oxygen is added, it ſeparates this phlogiſton, and the acid of courſe is precipitated. This hypotheſis was adopted by Macquer and Fontana; and theſe three philoſophers endeavoured to ſupport it with their uſual ingenuity. But there was one difficulty which they were unable to ſurmount. When the two gaſes are mixed in proper proportions, almoſt the whole aſſumes the form of nitric acid; and the ſmall reſiduum ($\frac{1}{34}$th part), in all probability, or rather certainly, depends on ſome accidental impurity in the oxygen gas. What then becomes of the oxygen and phlogiſton? Dr Prieſtley ſuppoſed that they formed carbonic acid gas: but Mr Cavendiſh proved, that when proper precautions are taken, no ſuch acid appears†.

† Phil. Tranſ. 1784.

Dr Prieſtley had procured his nitrous gas by diſſolving metals in nitric acid; during the ſolution of which a great deal of nitrous gas eſcapes. He ſuppoſed that nitrous gas contained phlogiſton, becauſe the metal was oxydated (and conſequently, according to the then received theory, muſt have loſt phlogiſton) during its formation. Mr Lavoiſier proved, that this ſuppoſition was ill-founded, by the following celebrated experiment‡. To 945 grains of nitric acid (ſpecific gr. 1,316) he added 1104 grains of mercury. During the ſolution 273,234 cubic inches of nitrous gas were produced. He then diſtilled the ſalt, (oxyd of mercury), which had been formed to dryneſs. As ſoon as it became red hot it emitted oxygen gas, and continued to do ſo till almoſt the whole of the mercury was revived: The quantity of oxygen emitted was 287,742 cubic inches. All that had happened, therefore, during the ſolution of the mercury, was the ſeparation of the acid into two parts; nitrous gas which flew off, and oxygen, which united with the metal (X).

‡ Mem. Par. 1776, p. 673.

Mr Lavoiſier concluded, therefore, that the whole of the nitrous gas was derived from the nitric acid: that nitric acid is compoſed of oxygen and nitrous gas; and that the proportions are nearly 64 parts by weight of nitrous gas, and 36 of oxygen gas.

But there was one difficulty which Mr Lavoiſier acknowledged he could not remove. The quantity of oxygen obtained by decompoſing nitric acid was often much greater than what was neceſſary to ſaturate the nitrous gas. Mr de Morveau attempted to account for this, but without ſucceſs§. Nitrous gas itſelf was evidently a compound: but the difficulty was to diſcover the ingredients. Mr Lavoiſier concluded from an experiment made by decompoſing nitre by means of charcoal, that it contained azot: and ſeveral of Dr Prieſtley's experiments led to the ſame reſult. But what was the other ingredient?

§ Encycl. Method. Chim. Acide Nitrique.

Mr Cavendiſh had obſerved, while he was making experiments on the compoſition of water, that ſome nitric acid was formed during the combuſtion of oxygen and hydrogen gas, and that its quantity was increaſed by adding a little azot to the two gaſes before the exploſion. Hence he concluded, that the formation of the acid was owing to the accidental preſence of

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(T) Nitre is compoſed of nitric acid and potaſs.

(U) Or nitrous acid: for at the period of Dr Prieſtley's diſcovery (1772) they were not accurately diſtinguiſhed.

(X) We have already mentioned, in a preceding note, that this experiment was firſt made by Mr Bayen. See Part I. chap. iii. of this Article.

of ſtandard acid employed was 66,7. The whole of which amounted to 102,75 grains; but as only 85,142 grains entered into the compoſition of the ſalt, the remaining 17,608 muſt have been pure water mixed with the nitric acid. But if 66,7 of ſtandard acid contain 17,608 of water, 100 parts of the ſame acid muſt contain 26,38[*].

[*] Iriſh ranſ. iv.

One hundred parts of ſtandard nitric acid, therefore, is compoſed of 73,62 parts of pure nitric acid and 26,38 of water. But as Mr Kirwan has not proved that nitrat of ſoda contains no water, perhaps the proportion of water may be greater. He has rendered it probable, however, that nitrat of ſoda contains very little water.

415 s action i other dies,

Nitric acid is decompoſed by a great variety of ſubſtances. When poured upon oils, it ſets them on fire. This is occaſioned by a decompoſition both of the acid and oil. The oxygen of the acid combines with the carbon, and with the hydrogen of the oils, and at the ſame time lets go a quantity of caloric. Hence we ſee that the oxygen which enters into the compoſition of the nitric acid ſtill contains a great deal of caloric; a fact which is confirmed by a great number of other phenomena. The combuſtion of oils by this acid was firſt taken notice of by Borrichius and Slare; but it is probable that Homberg communicated it to Slare. In order to ſet fire to the fixed oils, it muſt be mixed with ſome ſulphuric acid; the reaſon of which ſeems to be, that theſe oils contain *water*, which muſt be previouſly removed. The ſulphuric acid combines with this water, and allows the nitric acid, or rather the oil and nitric acid together, to act. The drying oils do not require any ſulphuric acid: they have been boiled, and conſequently deprived of all moiſture. It ſets fire alſo to charcoal, provided it be perfectly dry. This fact was firſt obſerved by Prouſt, and afterwards confirmed by the Dijon academicians. It ſets fire alſo to zinc, biſmuth and tin, if it be poured on them in fuſion, and to filings of iron, if they be perfectly dry[‡]. In all theſe caſes, the acid is decompoſed. Sulphurated hydrogen gas alſo takes fire, and burns with a ſtrong flame by means of this acid[†].

[‡] Prouſt, ijon Aca- nicians, id Cor- tte.

[†] Tromſ- rff.

It is capable of oxydating all the metals except gold, platinum (x), and titanium. It appears, from the experiments of Scheffer, Bergman, Sage, and Tillet, that nitric acid is capable of diſſolving (and conſequently of oxydating) a very minute quantity, even of gold.

416 s combinations,

Nitric acid combines with alkalies, alkaline earths, alumina and jargonia, and with the oxyds of metals, and forms compounds which are called *nitrats*. It does not act upon ſilica nor adamanta.

417 nd affinities.

The order of its affinities is as follows:

Barytes,
Potaſs,
Soda,
Strontites[*],
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia[†] ?
Metallic oxyds, in the ſame order as for ſulphuric acid,
Water.

[*] Dr Hope.

[†] Vauquelin, Ann. de Chim. xxii. 208.

SECT. IV. *Of Nitrous Acid.*

418 Component parts of nitrous acid.

If oxygen gas be mixed with nitrous gas, a quantity of red fumes appear, which are readily abſorbed by water. Theſe red fumes are *nitrous acid*.

If a glaſs veſſel containing nitric acid be inverted into another veſſel containing the ſame acid, and expoſed to the light, the inverted glaſs will become partly full of oxygen gas, and at the ſame time part of the nitric acid is converted into nitrous acid[*]. It follows, from this experiment, that nitrous acid contains leſs oxygen than nitric acid. Lavoiſier has calculated that it contains ſomewhat leſs than three parts of oxygen to one of azot.

[*] Scheele, Crell's Annals 1786.

419 Its properties.

Nitrous acid is of a brown or red colour, exceedingly volatile, and emitting a very ſuffocating, and ſcarcely tolerable odour. When to this acid concentrated, a fourth part by weight of water is added, the colour is changed from red to a fine green; and when equal parts of water are added, it becomes blue[†]. Dr Prieſtley obſerved, that water impregnated with this acid in the ſtate of vapour, became firſt blue, then green, and laſtly yellow. A green nitrous acid became orange-coloured while hot, and retained a yellow tinge when cold. A blue acid became yellow on being heated in a tube hermetically ſealed. An orange-coloured acid, by long keeping became green, and afterwards of a deep blue; and when expoſed to air reſumed its original colour. Theſe colours ſeem to depend upon the concentration of the acid.

[†] Bergman.

Dr Prieſtley found that water abſorbed great quantities of this acid in the ſtate of vapour, and that when ſaturated, its bulk was increaſed one-third.

In the ſtate of vapour, it is abſorbed rapidly by oils. Whale oil, by abſorbing it, became green, thick and heavier. It gradually decompoſed the acid, retained the oxygen, and emitted the azot in the ſtate of gas[‡].

[‡] Prieſtley, iii. 111.

It is abſorbed by ſulphuric acid, but ſeemingly without producing any change; for when water is poured into the mixture, the heat produced expels it in the uſual form of red fumes[§]. The only ſingular circumſtance attending this impregnation is, that it diſpoſes the ſulphuric acid to cryſtallize[*]. This fact, firſt obſerved by Dr Prieſtley in 1777 (y), was afterwards confirmed by Mr Cornette.

[§] Ibid. p. 144.

[*] Ibid. p. 156.

(x) Nitre however acts upon platinum, as Mr Tennant has proved. *Phil. Tranſ.* 1797. Morveau had made the ſame obſervation in the *Elemens de Chimie de l'Academie de Dijon.*

(y) Bernhardt, however, relates, in 1765, that once, when he was diſtilling a mixture of ten pounds of nitre with an equal quantity of calcined vitriol, which he had put into a retort, to which was fitted an adapter between the retort and the receiver, which contained a quantity of water—he obſerved a conſiderable quantity of a white cryſtalline ſalt formed in the adapter, while the liquid acid paſſed as uſual into the receiver. This ſalt was very volatile, ſmoked ſtrongly when it was expoſed to the air, and exhaled a red vapour; it burnt, to a black coal, wood, feathers or linen, as ſulphuric acid does; and where a piece of it fell, it evaporated in form of a blood-red vapour till the whole of it diſappeared. Half an ounce of theſe cryſtals diſſolved in water with ſpurt-

Nitrous acid appears capable of combining with moſt of the bodies with which nitric acid unites. The ſalts which it forms are called *nitrites*.

Its affinities have never been accurately examined. Bergman ſuppoſes them the ſame with thoſe of nitric acid.

Of Nitrous Gas.

420
Diſcovery of nitrous gas.

NITROUS gas was firſt obtained by Dr Hales, but its properties were diſcovered by Dr Prieſtley. It may be procured by diſſolving metals in nitric or nitrous acid, and catching the product by means of a pneumatic apparatus.

As nitrous acid is formed by combining nitrous gas and oxygen, it is evident that nitrous gas contains leſs oxygen than nitrous acid. According to Lavoiſier, it is compoſed of two parts of oxygen and one of azot.

421
Its properties.

Nitrous gas is elaſtic, and inviſible like common air. It extinguiſhes light, and inſtantly kills all thoſe animals that are obliged to breathe it. Its ſpecific gravity, according to Mr Kirwan, is 0,001458 ‡.

Dr Prieſtley found that water was capable of abſorbing about one-tenth of nitrous gas, and that by the abſorption it acquired an aſtringent taſte §. Water parts with all the nitrous gas it has imbibed on being frozen †.

Neither phoſphorus nor ſulphur ſeem capable of decompoſing nitrous gas.

Mr Linck, profeſſor at Roſtoc, found, that three parts of nitrous gas and two of hydrogen gas, obtained by ſulphuric acid and iron, are ſcarcely, or not at all, diminiſhed when expoſed to day-light over water. Common air is not more diminiſhed by this admixture kept a long time: but the mixture itſelf of theſe two gaſes is diminiſhed by the addition of new portions of nitrous gas. Mr Linck concludes, from this obſervation, that part of the oxygen of the nitrous gas combined with the hydrogen and formed water, and that the remaining oxygen and azot formed a mixture ſimilar to the air of the atmoſphere. Mr Vauquelin had previouſly made the ſame obſervation. The affinity of hydrogen, therefore, for oxygen is greater than that of azot.*

Oils imbibe nitrous gas with avidity, and decompoſe it.

Nitric acid abſorbs a vaſt quantity of it, and is by that means converted into nitrous acid.—Sulphuric acid alſo abſorbs it.

The moſt important property of nitrous gas is that of combining inſtantly with oxygen gas, and forming nitrous acid, which is inſtantly abſorbed by water. This property induced Dr Prieſtley to uſe nitrous gas as a teſt of the purity of common air. He mixed together equal bulks of theſe ſubſtances, and judged of the purity of the air by the diminution of bulk. The apparatus uſed for this purpoſe, which conſiſts of a graduated tube, has been called a *eudiometer*.

422
The eudiometer.

This eudiometer has been greatly improved by Fontana, but it is ſtill liable to uncertainty in its application. Perhaps the beſt eudiometer is ſulphuret of potaſs, which, as Morveau has diſcovered, abſorbs, on the application of heat, the whole oxygen in a given bulk of air almoſt inſtantaneouſly.

Dr Prieſtley found, that nitrous gas was decompoſed by paſſing electric exploſions through it.

Let us now conſider in what manner oxygen and azot are combined in the three ſubſtances which have been juſt deſcribed.

423
Manner which a and oxyg are comb ned.

It can hardly be conceived that azot is capable of combining with three different proportions of oxygen, and of being ſaturated with each: it is ſurely much more probable, that in nitrous gas the oxygen and azot ſaturate each other directly and completely; that nitrous acid is compoſed of nitrous gas and oxygen, and nitric acid of nitrous acid and oxygen. And this ſuppoſition is confirmed by conſidering that the ſtrength of affinity by which the oxygen is retained in each of theſe ſubſtances is very different. Some ſubſtances, as light, are capable of decompoſing nitric acid, by ſeizing ſome of its oxygen, and of converting it into nitrous acid; but they have no effect whatever upon nitrous acid or nitrous gas. Others, as biſmuth, copper, phoſphorus, and ſulphur, are capable of decompoſing both nitric and nitrous acids, but are incapable of altering nitrous gas: And others, again, as carbon, zinc, and iron, are capable of decompoſing all the three. Every body which is capable of decompoſing nitrous acid is capable alſo of decompoſing nitric acid; and every body that decompoſes nitrous gas is capable alſo of decompoſing the other two. But the reverſe of this is not true. The affinity of oxygen, then, for azot, nitrous gas, and nitrous acid, is different: oxygen has a ſtronger affinity for azot than it has for nitrous gas, and a ſtronger affinity for nitrous gas than for nitrous acid. But if all theſe bodies were direct combinations of azot and oxygen, how could this difference of affinity take place? Is it reaſonable to ſuppoſe, that a ſubſtance has a ſtronger affinity for one proportion of any other body than for another proportion? or that, if ſuch a difference exiſted, the ſtrongeſt affinity ſhould not always prevail? Mix together nitric acid and nitrous gas in proper proportions, and the whole mixture is converted into nitrous acid: but mix nitrous and nitric acids together, and no change whatever is produced. In the firſt caſe, is it not evident that the affinity of nitrous gas for oxygen is greater than that of nitrous acid; that therefore it decompoſes the nitric acid, deprives it of oxygen, and leaves it in the ſtate of nitrous acid? But, in the ſecond caſe, no change can take place, becauſe nitric acid is compoſed of nitrous acid and oxygen; and it would be abſurd to ſuppoſe, that *nitrous acid* has a ſtronger affinity for oxygen than *nitrous acid* has. But were azot and oxygen capable of uniting in various proportions, why ſhould not a mixture of nitric and nitrous acids, or of nitrous gas and nitrous acid, form new ſubſtances? And why are the only ſubſtances which appear in decompoſitions nitrous acid and nitrous gas? Surely theſe reaſons are ſufficient to ſhew us, that theſe bodies are combined in the following manner:

Azot

‡ *On Phlogiſton*, p. 28.

§ *Prieſtley*, i. 365.

† *Ibid.* p. 407.

* *Nicholſon's Jour.* ii. 72.

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ing and hiſſing, like that of a red hot iron dipped in water, and formed a green nitrous acid. Some of this ſalt being put into a bottle which was not well ſtopped, entirely vaniſhed. Theſe cryſtals were evidently the ſame with Dr Prieſtley's. See *Keir's Dictionary*.

Azot and Oxygen } form nitrous gas;
Nitrous gas and oxygen } form nitrous acid;
Nitrous acid and oxygen } form nitric acid. (22)

Perhaps there may be even more links in the chain than we are aware of. The dephlogiſticated nitrous air of Dr Prieſtley, which Dieman and Van Trooſtwyck have lately proved to be compoſed of 37 parts of oxygen and 63 of azot, and of which little more is known than that it ſupports flame, is noxious to animals, abſorbed by water, and only obtained by means of ſubſtances capable of decompoſing nitrous gas—perhaps this *air* is compoſed directly of oxygen and azot, nitrous gas of this air and oxygen, and ſo on. There may be even links ſtill farther back than that.

Sect. V. *Of Muriatic Acid.*

424
iſcovery muriatic id.

Muriatic acid appears to have been known to Bazil Valentine; but Glauber was the firſt who extracted it from common ſalt by means of ſulphuric acid. Common ſalt is compoſed of muriatic acid and ſoda, for which laſt ſubſtance ſulphuric acid has a ſtronger affinity. This acid was firſt called *ſpirit of ſalt*, afterwards *marine acid*, and now, pretty generally, *muriatic acid* ‡.

From mu-

It is ſometimes prepared by mixing one part of common ſalt with ſeven or eight parts of clay, and diſtilling the mixture. The clay, in this inſtance, is ſuppoſed to act chiefly by means of the ſulphuric acid which it always contains (z): But this ſubject ſtill requires farther elucidation. By theſe proceſſes, muriatic acid is obtained diſſolved in water. Dr Prieſtley diſcovered, that by applying heat to this ſolution, and receiving the product in veſſels filled with mercury, a gas was procured; which gas is muriatic acid in a ſtate of purity.

425
Its properties.

Muriatic acid gas is inviſible and elaſtic, like common air. It deſtroys life and extinguiſhes flame. A candle, juſt before it goes out in it, burns with a beautiful green, or rather light blue flame; and the ſame flame appears when it is firſt lighted again.*

The ſpecific gravity of muriatic acid in the ſtate of gas is, according to Mr Kirwan †, 0,002315, which is nearly double that of common air.

Water abſorbs this gas with avidity. Ten grains of water are capable of abſorbing ten grains of the gas. The ſolution thus obtained occupies the ſpace of 13,3 grains of water nearly. Hence its ſpecific gravity is 1,500, and the denſity of the pure muriatic acid in it is 3,03* (A).

As muriatic acid can only be uſed conveniently when diſſolved in water, it is of much conſequence to know how

* *Prieſtley*, II. 293.

† *Iriſh Tranſ.* IV.

* *Kirwan, Iriſh Tranſ.* vol. iv.

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(22) To account for theſe phenomena, we would again appeal to the principle of the affinity of two ſubſtances leſſening in proportion to their mutual ſaturation. As the nitric acid is nitrogen *ſaturated* with oxygen, nitrous acid nitrogen combined with a leſs portion of oxygen, and nitrous air nitrogen combined with a ſtill leſs portion of oxygen, it would be eaſy on this principle to account for a body which partially decompoſed nitric acid not effecting the other two combinations, and it would follow from the ſame principles that any ſubſtance which would decompoſe nitrous air would decompoſe both the others. When we mix nitric acid with nitrous air it forms nitrous acid, ſo it ſhould according to this explanation. The nitrogen in the nitrous air being combined with a ſmaller portion of oxygen, has a ſtronger affinity for oxygen than the nitrogen in nitric acid has: It therefore partially decompoſes the nitric acid, combines with part of its oxygen, thus reduces it to the ſtate of nitrous acid while it paſſes on to the ſame ſtate itſelf, and then their affinity for oxygen being equal, the decompoſition ceaſes and they form an homogeneous acid. But, ſays he, nitric and nitrous acids undergo no change when mixed. How does he know that no change is made? Have the two acids ever been mixed and then ſeparated without any change having taken place in them? If they have, and the nitrous acid made uſe of did not nearly approach to the ſtate of nitric acid, it will at leaſt be a plauſible though not a concluſive argument. But where is he to fix his firſt ſtep, or the point of ſaturation? It already appears that nitrous air is not oxygen and nitrogen, but it is the *dephlogiſticated nitrous air* of Dr Prieſtley united to oxygen. If by any proceſs this is partially decompoſed, it will then appear that it is not nitrogen combined with oxygen, but the new combination of theſe gaſes which remains and oxygen. Thus, however ſmall a portion of oxygen we may find combined with nitrogen, we are to take it for granted that it is ſaturated. Theſe too are the arguments on which he founds his theory of the oxyd of a metal which contains the ſmalleſt portion of oxygen being ſaturated and that the other oxyds of it are but a combination of oxygen to the compound. Thus the grey oxyd of lead would be with him lead ſaturated with oxygen, the yellow oxyd the grey oxyd combined with oxygen, and the red oxyd, the yellow oxyd oxygenated. I muſt confeſs I cannot ſee the force of his obſervations. He has not, as far as I can ſee, adduced a ſingle argument to prove that the oxygen does not unite immediately to the metal, which is certainly a much more rational idea than to ſuppoſe it unites to the oxyd. T. P. S.

(z) Morveau has ſhown, that even alumina contains ſulphuric acid, provided a precipitation, on adding muriat of barytes, be a ſufficient teſt.

(A) For let D = the denſity of a mixture; *m* the weight of the denſer ingredient; *d* its denſity; *l* the weight of an equal bulk of water; and *m'*, *d'*, and *l'*, the ſame elements of the rarer: Then $D = \frac{m+m'}{l+l'}$. In the above caſe, $m + m' = 20$, and $l + l' = 13{,}3$. Then $D = \frac{20}{13{,}3} = 1{,}5$. Now to find the ſpecific gravity of the condenſed

Oxy-muriatic Acid.

how much pure acid is contained in a given quantity of liquid muriatic acid of any particular denſity.

426
Quantity of it contained in acids of various denſitics.

Now the ſpecific gravity of the pureſt muriatic acid that can eaſily be procured and preſerved, is 1,196; it would be needleſs, therefore, to examine the purity of any muriatic acid of ſuperior denſity. Mr Kirwan calculated that muriatic acid, of the denſity 1,196, contains $\frac{49}{100}$ parts of acid of the denſity 1,500, which he took for the ſtandard; then, by means of experiments, he formed the following table:

100 parts, at the ſpecific gravity	contain of ſtandard acid	100 parts, at the ſpecific gravity	contain of ſtandard acid	100 parts, at the ſpecific gravity	contain of ſtandard acid
1,196	49	1,147	37	1,1036	26
1,191	48	1,1414	36	1,0984	25
1,187	47	1,1396	35	1,0942	24
1,183	46	1,1358	34	1,0910	23
1,179	45	1,1320	33	1,0868	22
1,175	44	1,1282	32	1,0826	21
1,171	43	1,1244	31	1,0784	20
1,167	42	1,1206	30	1,0742	19
1,163	41	1,1168	29	1,0630	16
1,159	40	1,1120	28	1,0345	10
1,155	39	1,1078	27	1,0169	5
1,151	38				

Muriatic acid (for this ſolution of the acid in water is always called by that name) is generally of a pale yellow colour, owing, as Dr Prieſtley ſuppoſed, to ſome earthy matter diſſolved in it; but much more probably to its having abſorbed a quantity of oxygen, for which it has a ſtrong affinity. Indeed, that this is the cauſe appears evidently from Dr Prieſtley's own obſervations; for it was deſtroyed only by thoſe bodies which had a ſtronger affinity for oxygen. It is very volatile, as might be expected, conſtantly emitting white fumes of a peculiar and unpleaſant odour.

427
Its action on other bodies.

Muriatic acid is capable, by the aſſiſtance of heat, of oxydating the following metals: Iron, tin, lead, zinc, biſmuth, cobalt, nickel, mangancſe, antimony, arſenic. Several of theſe, as iron for inſtance, it oxydates even without the aſſiſtance of heat.

At a boiling heat, it oxydates ſilver and copper. It has no action on gold, platinum, mercury, tungſten, molybdenum, tellurium, titanium. Its action on uranium has not been tried.

In the ſtate of gas, it appears to decompoſe alcohol and oils by its affinity for water.*

It is capable of diſſolving a little ſulphat and fluat † of lime, and arſeniat of mercury.

It combines with the alkalies, alkaline earths, alumina, and jargonia, and with moſt of the metallic oxyds, and forms neutral ſalts, known by the name of *muriats*.

428
Deſtroys putrid m. ſmata.

Morveau firſt ſhewed, that this acid, in the ſtate of gas, neutralized putrid miaſmata, and by that means deſtroyed their bad effects. In 1773, the cathedral of Dijon was ſo infected by putrid exhalations, that it was deſerted, after ſeveral unſucceſsful attempts to purify it. Application was made to Mr Morveau to ſee whether he knew any method of deſtroying theſe exhalations. He poured two pounds of ſulphuric acid on ſix pounds of common ſalt, contained in a glaſs capſule, which had been placed on a few live coals in the middle of the church. He withdrew precipitately, and ſhut all the doors. The muriatic acid gas ſoon filled the whole cathedral, and could even be perceived at the door. After 12 hours, the doors were thrown open, and a current of air made to paſs through to remove the gas. This deſtroyed completely every putrid odour ‡.

429
Its affiniti

The affinities of muriatic acid are as follows:

Barytes,
Potaſs,
Soda,
Strontites ‡,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia,*
Metallic oxyds as in ſulphuric acid,
Water.

Sect. VI. *Of Oxy-muriatic Acid.*

430
Diſcover and prep ration of oxy-muri tic acid.

Put into a glaſs retort one part of the black oxyd of mangancſe and three parts of muriatic acid; place it in a ſand-bath in ſuch a manner that the liquor which riſes up into the neck of the retort may fall back again into the veſſel; and apply a ſmall receiver, with a little water in it, luted to the retort merely by a fillet of brown paper. In about a quarter of an hour the receiver will appear filled with a yellow-coloured gas; it is then to be removed, and others applied ſucceſſively till the operation be finiſhed.

This gas is oxy-muriatic acid, firſt diſcovered by Scheele, while he was making experiments on mangancſe, and called by him *dephlogiſticated muriatic acid*, becauſe he thought it muriatic acid deprived of phlogiſton. The French chemiſts called it *oxygenated muriatic acid*, which Dr Pearſon contracted into *oxy-muriatic acid*; and this laſt name we have adopted, becauſe it is ſhorter and equally diſtinct.

431
Its compoſition.

The true theory of the formation and compoſition of this acid, which was firſt given by Berthollet, will appear from the following facts: The *black* oxyd of mangancſe is, during the proceſs, converted into *white* oxyd, and muſt therefore have given out a quantity of oxygen. When oxy-muriatic acid diſſolved in water is preſented to the light in a veſſel half empty, oxygen gas is diſengaged and floats above, and the acid is converted

* *Prieſtley*, II. 281.

† See ſect. ix.

‡ *Jour. d Phyſ.* i. 43

‡ *Dr Hop*

* *Vauquel Ann. de Chim.* xxi 208.

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condenſed muriatic acid gas, we have from the above equation $l = \frac{m + m' - l' D}{D} = \frac{5}{1,5} = 3,3$; and $d = \frac{m}{l} = \frac{10}{3,3} = 3,03$. *See Iriſh Tranſactions*, vol. iv.

This calculation, however, is formed upon the ſuppoſition that the water ſuffers no condenſation at all—a ſuppoſition certainly contradicted by every analogy, and which, as Mr Keir has ſhewn, the experiments mentioned in Mr Kirwan's firſt paper are inſufficient to prove.

verted into common muriatic acid: Conſequently oxy-muriatic acid is compoſed of muriatic acid and oxygen. Black oxyd of mangaueſe is compoſed of white oxyd and oxygen; muriatic acid has a ſtronger affinity for oxygen than the white oxyd; during the diſtillation the black oxyd is decompoſed, the oxygen combines with muriatic acid, and the product is oxy-muriatic acid gas.

432
proper-
ti.

Oxy-muriatic acid gas is of a yellow colour. It ſupports flame, but cannot be breathed without proving noxious. The death of the ingenious and induſtrious Pelletier, to whom we have ſo often referred, was occaſioned by his attempting to reſpire it. A conſumption was the conſequence of this attempt, which, in a ſhort time, proved fatal.

It does not unite readily with water. Scheele found, that after ſtanding 12 hours over water, $\frac{4}{5}$ths of the gas were abſorbed: the remainder was common air, which no doubt had been contained in the veſſel before the operation. Berthollet ſurrounded ſeveral bottles containing it with ice: as ſoon as the water in theſe bottles was ſaturated, the gas became concrete, and ſunk to the bottom of the veſſels; but the ſmalleſt heat made it riſe in bubbles, and endeavour to eſcape in the form of gas[*]. Weſtrum obſerved that it became ſolid when expoſed in large veſſels to the temperature of 40°; and that then it exhibited a kind of cryſtallization[†]. The ſpecific gravity of water ſaturated with this gas at the temperature of 43°, is 1,003[‡]. Water impregnated with it has not an acid, but an auſtere taſte[§], unlike that of other acids.

[*] our. de
yſ. 1785.
[†] our. de
yſique,
vii. 382.
[‡] erthollet,
r. de
yſ. 1785.
[§] Scheele.

It renders vegetable colours *white*, and not red, as other acids do; and the colour thus deſtroyed can neither be reſtored by acids nor alkalies. It has the ſame effects on yellow wax. If the quantity of vegetable colours to which it is applied be ſufficiently great, it is found reduced to the ſtate of common muriatic acid. Hence it is evident, that it deſtroys theſe colours by communicating oxygen. This property has rendered oxy-muriatic acid a very important article in bleaching.

Nitrous gas, hydrogen, ſulphur, ſulphurous acid, and phoſphorus, decompoſe this acid, by depriving it of its oxygen, and leaving the muriatic acid in a ſeparate ſtate. Phoſphorus, however, does not produce this effect ſo readily, except when aſſiſted by heat[*].

[*] Morveau,
cycl.
ethod.
imie I.
I.

433
tro-mu-
tic acid.

When muriatic acid is mixed with nitric acid, the compound has preciſely the ſmell and the qualities of oxy-muriatic. It can ſcarcely be doubted, therefore, that as far as it acts as an acid, different from the muriatic and the nitric, it is nothing elſe but oxy-muriatic acid.

This mixture of the two acids was formerly called *aqua regia*; but at preſent it is called by the French chemiſts *nitro-muriatic acid.* It is firſt mentioned by Iſaac the Hollander, and ſeems to have been known before the muriatic acid itſelf. It was prepared by pouring nitric acid on common ſalt. The nitric acid decompoſes the ſalt, and part of it unites with the muriatic acid thus ſet at liberty.

434
Its action on other bodies.

Oxy-muriatic acid oxydates all the metals (except, perhaps, titanium) without the aſſiſtance of heat.

It decompoſes red ſulphuret of mercury, or cinnabar, which neither ſulphuric nor nitric acid is able to accompliſh[†].

[†] Bergman.

All the ſubſtances placed before muriatic acid in the table of the affinities of oxygen, are capable of decompoſing this acid. Many of them, when plunged into it while in the ſtate of gas, actually take fire. Weſtrum obſerved, for inſtance, that when pieces of wood were plunged into this gas, they took fire; that arſenic burned with a blue and green flame; biſmuth, with a lively bluiſh flame; nickel, with a white flame, bordering on yellow; cobalt, with a white flame, approaching to blue; zinc, with a lively white flame; tin, with a feeble bluiſh flame; lead, with a ſparkling white flame; copper and iron, with a red flame: that powdered charcoal took fire in it at the temperature of 90°, and that ammonia produced with it a loud detonation[‡].

[‡] Jour. de Phyſique, xxxvii. 385.

With alkalies, earths, and metallic oxyds, it is capable of combining and forming neutral ſalts, which have been called *oxy-muriats*.

435
Its affinities.

The affinities of this acid, according to Lavoiſier, are as follows:

Alumina,
Jargonia[*]?
Ammonia,
Oxyd of antimony,
——— Silver,
——— Arſenic,
Barytes,
Strontites?
Oxyd of biſmuth,
Lime,
Oxyd of cobalt,
——— Copper,
——— Tin,
——— Iron,
Magneſia (B),
Oxyd of manganeſe,
——— Mercury,
——— Molybdenum,
——— Nickel,
——— Gold,
——— Platinum,
——— Lead,
Potaſs,
Soda,
Oxyd of tungſten,
——— Zinc (C).

[*] Vauquelin, Ann. de Chim. xxii. 208.

436
Of the component parts of muriatic acid.

The component parts of muriatic acid are ſtill imperfectly known. Dr Girtanner pretended, about the year 1790, that he had decompoſed it; and that it conſiſted of hydrogen combined with a greater proportion of oxygen than enters into the compoſition of water. He paſſed electrical exploſions through muriatic acid,

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(B) According to Tromſdorf, oxy-muriatic acid is incapable of combining with magneſia. *Ann. de Chim.* xxii. 218.

(C) This is the order of the affinities of nitro-muriatic acid. Many facts (ſome of which ſhall appear afterwards) concur to prove that the affinities of the oxy-muriatic acid are the ſame, and indeed that they are the ſame acids.

oſphoric Acid.

Lavoiſier computes, that phoſphoric acid contains 100 parts of phoſphorus and 154 of oxygen.

439 proper- ies.

The colour of this acid is white; it has no ſmell, has an acid taſte, but is not corroſive(E.)

It is exceedingly fixed. When expoſed to the fire in a matraſs with a long neck, it loſes at firſt the greater part of its water; then an odour of garlic is felt, owing to ſome phoſphorus from which it is exceedingly difficult to clear it entirely; there is likewiſe a ſmall quantity of the acid volatilized along with the water. The liquor then becomes thick and milky: ſmall luminous decrepitations take place from time to time, and they continue for ſome time after the veſſel is taken from the fire. If the matter be then put into a crucible and placed among burning coals, it firſt boils violently, and gives out a vapour which tinges flame green, and is at laſt converted to a white tranſparent glaſs, inſoluble in water.

The ſpecific gravity of this acid in a ſtate of dryneſs is 2,687†, that of phoſphoric acid by deliqueſcence 1,417*. It is capable of cryſtallizing; its cryſtals are quadrangular priſms terminated by quadrangular pyramids.

† ergman. * Morveau.

Phoſphoric acid obtained by deliqueſcence, when mixed with an equal quantity of diſtilled water, acquired ſo little *heat* as to raiſe the thermometer only one degree, as Mr Sage obſerved.

Mr Lavoiſier raiſed Reaumur's thermometer from 8° to 14° or 15° by mixing phoſphoric acid boiled to the conſiſtence of a ſyrup, with an equal quantity of water; and from 8° to 32° or 33° when the acid was as thick as turpentine*.

* Keir's ionary.

440 action other dies.

Phoſphoric acid is capable of oxydating iron, tin, lead, zinc, antimony, biſmuth, mangane ſe. When fuſed with ſeveral of theſe metals, as tin, lead, iron, and zinc, it is converted into phoſphorus; a proof that they have a ſtronger affinity for oxygen.

It does not act upon gold, platinum, ſilver, copper, mercury, arſenic, cobalt, nickel. It appears, however, to have ſome action on gold in the *dry way*, as it is called; for when fuſed with gold-leaf, it aſſumes a purple colour; a proof that the gold has been oxydated.

It is capable of combining with alkalies, alkaline earths, alumina, and metallic oxyds; and of forming ſalts, known by the name of *phoſphats*.

Phoſphoric acid, by the aſſiſtance of heat, is capable of decompoſing glaſs.

441 affinities.

Its affinities are as follows:

Lime,
Barytes,
Strontites‡
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia*,
Metallic oxyds, as in ſulphuric acid,
Water.

‡ Hope, anſ. in. IV.

* Vauque , Ann. de im. xxii. 8.

442 hoſpho- us acid.

The Phosphorous Acid is formed when phoſphorus is expoſed to a ſlow ſpontaneous combuſtion at the temperature of the atmoſphere; but it gradually abſorbs more oxygen, and is converted into phoſphoric acid.

Boracic Acid.

Concerning phoſphorous acid, nothing of any conſequence is at preſent known, except that it contains leſs oxygen than phoſphoric acid.

Sect. VIII. *Boracic Acid.*

443 Borax.

The word *borax* firſt occurs in the works of Geber, an Arabian chemiſt of the tenth century. It is a name given to a ſpecies of white ſalt much uſed by various artiſts. Its uſe in ſoldering metals appears to have been known to Agricola.

Borax is found mixed with other ſubſtances in Thibet. It ſeems to exiſt in ſome lands adjacent to lakes, from which it is extracted by water, and depoſited in thoſe lakes: whence in ſummer, when the water is ſhallow, it is extracted and carried off in large lumps. Sometimes the water in theſe lakes is admitted into reſervoirs, at the bottom of which, when the water is exhaled by the ſummer's heat, this ſalt is found.—Hence it is carried to the Eaſt-Indies, where it is in ſome meaſure purified and cryſtallized: in this ſtate it comes to Europe, and is called *tincal.* In other parts of Thibet, it ſeems, by accounts received from China, they dig it out of the ground at the depth of about two yards, where they find it in ſmall cryſtalline maſſes, called by the Chineſe *mi poun*, *houi poun*, and *pin poun*; and the earth or ore is called *pounxa**.

* *Kirwan's Mineralogy*, ii. 37.

444 Diſcovery of boracic acid.

Though borax has been in common uſe for nearly three centuries, it was only in 1702 that Homberg, by diſtilling a mixture of borax and green vitriol, diſcovered the *boracic acid.* He called it *narcotic* or *ſedative ſalt*, from a notion of his that it poſſeſſed the properties indicated by theſe names. In his opinion, it was merely a product of the vitriol which he had uſed; but Lemery the Younger ſoon after diſcovered, that it could likewiſe be obtained from borax by means of the nitric and muriatic acids. Geoffroi afterwards diſcovered, that borax contained ſoda; and at laſt Baron proved, by a number of experiments, that borax was compoſed of boracic acid and ſoda; that it might be reproduced by combining theſe two ſubſtances—and that therefore the boracic acid was not formed during the decompoſition of borax as former chemiſts had imagined, but was a peculiar ſubſtance which pre-exiſted in that ſalt.

445 Attempts to prove that it does not exiſt in borax;

This concluſion has been called in queſtion by Mr Cadet*; who affirmed, that it was compoſed of *ſoda, the vitrifiable earth of copper, another unknown metal, and muriatic acid.* But this aſſertion has never been confirmed by a ſingle proof; Mr Cadet has only proved, that boracic acid ſometimes contains copper; and Beaumé's experiments are ſufficient to convince us, that this metal is merely accidentally preſent, and that it is probably derived from the veſſels employed in cryſtallizing borax: That boracic acid generally contains a little of the acid employed to ſeparate it from the ſoda, with which it is combined in borax: And that crude borax contains a quantity of earth imperfectly ſaturated with boracic acid:—All which may be very true; but they are altogether inſufficient to prove that bora-

* *Journ. de Phyſ.* 1782.

cic

(E) We have obſerved, however, that when very much concentrated it deſtroyed the texture of vegetable ſubſtances, paper, for inſtance, very completely.

cic acid is not a peculiar ſubſtance, ſince it diſplays properties different from every other body.

446 And to prove that it is phoſphoric acid. Meſſrs Exſchaquet and Struve have endeavoured, on the other hand, to prove, that the phoſphoric and boracic acids are the ſame. But their experiments merely ſhew, that theſe acids reſemble one another in ſeveral particulars; and though they add conſiderably to our knowledge of the properties of the phoſphoric acid, they are quite inadequate to eſtabliſh the principle which theſe chemiſts had in view; ſince it is not ſufficient to prove the identity of the two acids, to ſhew us a reſemblance in a few particulars, while they differ in many others. Boracic acid muſt therefore be conſidered as a diſtinct ſubſtance, the component parts of which are entirely unknown.

447 Method of procuring it. The eaſieſt method of procuring boracic acid is the following one: Diſſolve borax in hot water, and filter the ſolution; then add ſulphuric acid, by little and little, till the liquor be rather more than ſaturated. Lay it aſide to cool, and a great number of ſmall, ſhining, laminated cryſtals will form. Theſe are the boracic acid. They are to be waſhed with cold water, and drained upon brown paper.

448 Its properties. This acid has a ſouriſh taſte at firſt, then makes a bitteriſh cooling impreſſion, and at laſt leaves an agreeable ſweetneſs. Its cryſtals have ſome reſemblance to ſpermaceti, and it has the ſame kind of feel.

It changes vegetable blues to red; it has no ſmell; but when ſulphuric acid is poured on it, a tranſient odour of muſk is produced*. The air produces no change on it.

According to Reuſs, it is ſoluble in 20 parts of cold water, eight parts of warm water, and 2,5 of boiling water. According to Wenzel, 960 grains of boiling water, diſſolve 434 of this acid. According to Morveau, one pound of boiling water diſſolves only 183 grains.

It is exceedingly fixed when not combined with water. When expoſed to a violent fire it is converted into a white tranſparent glaſs; which, however, is ſoluble in water, and produces the acid again by evaporation.

Boracic acid is alſo ſoluble in alcohol; and alcohol containing it burns with a green flame.

Its ſpecific gravity is 1,479†.

Paper dipped into a ſolution of boracic acid burns with a green flame.

Though mixed with fine powder of charcoal, it is nevertheleſs capable of vitrification; and with ſoot it melts into a black bitumen-like maſs, which is, however, ſoluble in water, and cannot be eaſily calcined to aſhes, but ſublimes in part†.

With the aſſiſtance of a diſtilling heat it diſſolves in oils, eſpecially in mineral oils, and with theſe it yields fluid and ſolid products, which give a green colour to ſpirit of wine.

When boracic acid is rubbed with phoſphorus, it does not prevent its inflammation, but an earthy yellow matter is left behind†.

449 Its action on other bodies. It is hardly capable of oxydating, or diſſolving any of the metals except iron and zinc, and perhaps copper.

Boracic acid combines with alkalies, alkaline earths, and alumina, and moſt of the metallic oxyds, and forms compounds which are called *borats*.

450 Its affinities. Its affinities are as follows

Lime,
Barytes,
Strontites‡,
Magneſia,
Potaſs,
Soda,
Ammonia,
Oxyd of zinc,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— mercury,
Alumina,
Jargonia§,
Water,
Alcohol.

SECT. IX. *Fluoric Acid.*

451 Diſcover of fluori acid. THE mineral called *fluor* or *fuſible ſpar*, was not properly diſtinguiſhed from other ſpars till Margraf publiſhed a diſſertation on it in the Berlin Tranſactions for 1768. He firſt proved, that it contained no ſulphuric acid, as had been formerly ſuppoſed; he then attempted to decompoſe it, by mixing together equal quantities of this mineral and ſulphuric acid, and diſtilling them. By this method he obtained a *white ſublimate*, which he ſuppoſed to be the fluor itſelf volatilized by the acid. He obſerved, with aſtoniſhment, that the glaſs retort was corroded, and even pierced with holes. Nothing more was known concerning fluor till Scheele publiſhed his experiments three years after; by which he proved, that it was compoſed chiefly of lime and a particular acid which has been called *fluoric acid.*

452 Method obtainin it. To obtain it, put eight ounces of finely powdered fluor into a retort, and pour on it an equal quantity of ſulphuric acid, and lute to the retort as exactly as poſſible, a receiver containing eight ounces of water. Vapours immediately appear and darken the inſide of the veſſel: Theſe are the acid in the ſtate of gas. The diſtillation is to be conducted with a very moderate heat, not only to allow the gas to condenſe, but alſo to prevent the fluor itſelf from ſubliming. After the proceſs, a cruſt of white earth is found in the receiver, which has all the properties of ſilica.

Scheele ſuppoſed, that the ſilica produced was formed of fluoric acid and water; and Bergman adopted the ſame opinion. But Wiegleb and Buccholz ſhewed, that the quantity of ſilica was exactly equal to what the retort loſt in weight; and Meyer completed the proof that it was derived from the glaſs, by the following experiment: He put into each of three equal cylindrical tin veſſels a mixture of three oz. of ſulphuric acid and one oz. of fluor, which had been pulverized in a mortar of metal. Into the firſt he put one oz. of pounded glaſs; into the ſecond, the ſame quantity of quartz in powder; and into the third, nothing. Above each of the veſſels he hung a ſponge moiſtened with water; and having covered them, he expoſed them to a moderate heat. The ſponge in the firſt cylinder was covered with the cruſt in half an hour; the ſponge in the ſecond in two hours; but no cruſt was formed in the third, though it was expoſed ſeveral days. In conſequence of this deciſive experiment, Bergman gave up his opinion, and wrote an account of Meyer's

* Reuſs De Sale Sedat. 1778.

† Kirwan's Miner. ii. 4.

† Keir's Dictionary.

† Ibid.

‡ Dr H Tranſ. Edin. IV

§ Vauqu lin, Ann. Chim. xx 208.

oric cid.

Meyer's experiment to Morveau, who was employed in tranſlating his works, to enable him to correct the miſtake in his notes.

3 Att pts prove ts ſt- nc

Soon after the diſcovery of this acid, difficulties and doubts concerning its exiſtence as a peculiar acid were ſtarted by ſome French chemiſts, diſguiſed under the name of Boulanger, and afterwards by Mr Achard and Mr Monnet. To remove theſe objections, Mr Scheele inſtituted and publiſhed a new ſet of experiments; which not only completely eſtabliſhed the peculiar nature of the fluoric acid, but once more diſplayed the unrivalled abilities of the illuſtrious diſcoverer. Theſe important particulars we paſs over thus ſlightly, becauſe they have been partly treated of already in the article CHEMISTRY (*Encycl.*) One experiment, however, we cannot omit, becauſe it is ſufficient of itſelf to deſtroy almoſt all the objections of his antagoniſts, which conſiſted in attempting to prove, that the fluoric acid was merely a modification of the acid employed to extract it. We ſhall give it in Mr Scheele's own words.

54 ed by le,

"I melted together (ſays he) in a crucible two ounces of finely pulverized fluor ſpar with four ounces of potaſs. As ſoon as they were melted, I poured out the maſs, rubbed it, when it was become cold, to a powder, and extracted the alkali from it again by lixiviation with water. I evaporated the lixivium to dryneſs; and threw away the remaining undiſſolved powder (which was only one of the component parts of the fluor, and which diſſolved readily, and with effervescence, in acids) from its ſolution, in which it may be precipitated by ſulphuric acid in the form of ſelenite (ſulphat of lime). Upon a little of the dried alkali, put into a ſmall retort, I poured ſome ſulphuric acid, fitted to it a receiver containing ſome water; and even before the retort was become hot, I obſerved this water to be covered over with a pellicle of ſiliceous earth: a certain proof that the alkali had extracted the acid from the fluor during its expoſure to the fire with it. Should Mr Achard, agreeably to the opinion which he has adopted, conclude from this experiment, that the alkali ſeparated the volatile earth from the fluor (F); ſtill he muſt certainly allow this earth of his to be of an acid nature, ſince the alkali is capable of diſengaging it from the calcareous earth.—The remaining portion of the dried alkali I diſſolved again in water, and ſaturated the ſuperfluous alkali with pure nitric acid. After expelling from this ſaturated ſolution, by means of heat, the carbonic acid gas, which in ſuch caſes is always retained in the liquor, I dropped ſome of it into lime-water; whereupon I obtained a white precipitate, which was a regenerated fluor. I now diſſolved ſome oxyd of lead in vinegar, and continued to add to the ley, which had been ſaturated with nitric acid, as much of this ſolution as was requiſite, till all precipitation ceaſed. Thus I transferred the fluor acid from the alkali to the oxyd of lead. After waſhing the precipitate in cold water, and drying it, I dropped upon a ſmall quantity of it a few drops of ſulphuric acid: a frothing up immediately enſued, accompanied with an extrication of fluor acid vapours. But perhaps, in this caſe, the volatile earth of fluor unites with the ſulphuric acid, and converts this fixed, or almoſt fixed acid into acid gas. I can eaſily make allowance to Dr Prieſtley for being inclined to draw ſuch a concluſion, ſince this celebrated philoſopher does not pretend to be a chemiſt (G). Being deſirous of ſeeing whether heat alone was capable of expelling this acid from the oxyd of lead, I put a little of this fluorated oxyd into a ſmall retort, the receiver to which contained ſome water. The oxyd was melted; but I could not perceive any acid. The bottom of the retort was moreover quite corroded and diſſolved, ſo that the whole ran into the fire. Thus the oxyd of lead retains this acid in the fire, and will not part with it, unleſs the oxyd is combined with ſome other ſubſtance. I therefore rubbed the remainder of my fluorated oxyd of lead with an equal quantity of charcoal powder, and diſtilled the mixture in an open fire in a ſmall glaſs retort, to which was adapted a receiver containing ſome water. As ſoon as the reduction of the oxyd of lead took place, the neck of the retort became incruſted with a white ſublimate, and a ſiliceous pellicle appeared upon the water. The ſublimate had a ſour taſte, becauſe the ſiliceous earth of which it conſiſts is penetrated with fluoric acid; and the acid water in the receiver let fall, on the addition of volatile alkali, a ſiliceous earth†."

Fluoric Acid.

Sorry are we to add, that ſince the death of this admirable man, to uſe the words of Mr Kirwan‡, a man as eminent in the chemical as Newton in the mathematical branch of natural philoſophy, Mr Monnet§ has thought proper to renew his attacks in a ſtyle of haughtineſs and acrimony that inſpires infinite diſguſt. The fallacy of his reaſoning is ſufficiently expoſed by Mr Leonhardi, in the 6th volume of his late learned edition of Macquer's Dictionary.

† *Crell's Journal*, I. 222. *Engliſh tranſlation.*

‡ *Mineralogy*, I. 126.

§ *Journ. de Phyſ.* xxx. 253.

455 And Leonhardi.

Fluoric acid may be obtained in the form of gas, by applying a moderate heat to ſulphuric acid and fluor ſpar, and receiving the product over mercury.

456 Its properties.

This gas is the acid in a ſtate of purity. It is inviſible and elaſtic like air; it does not maintain combuſtion, nor can animals breathe it without death. It has a pungent ſmell, not unlike that of muriatic acid.

It is heavier than common air. It corrodes the ſkin almoſt inſtantly. It combines rapidly with water; and if it has been obtained by means of glaſs veſſels, it depoſits at the ſame time a quantity of ſilica.

Water impregnated with this gas does not freeze at a higher temperature than 23°*.

* *Prieſtley*, ii. 362.

457 Its action on other bodies.

In the ſtate of gas this acid does not act upon nitrous gas nor ſulphur. Alcohol and ether abſorb it, but it does not alter their qualities†.

† *Ibid.*

It is capable of oxydating iron, zinc, copper, and arſenic.

It does not act upon gold, platinum, ſilver, mercury, lead, tin, antimony, cobalt.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms compounds denominated *fluats*.

It is capable, as we have ſeen, of diſſolving ſilica, which is inſoluble in every other acid; accordingly it corrodes

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(F) Mr Achard affirmed, that fluor was compoſed of a peculiar volatile earth.

(G) Dr Prieſtley at firſt advanced this hypotheſis; but he afterwards gave it up.

corrodes glaſs. This property has induced ſeveral ingenious men to attempt, by means of it, to engrave, or rather etch, upon glaſs.

458
Its affinities.

The affinities of fluoric acid are as follows:

Lime,
Barytes,
Strontites*,
Magneſia,
Potaſs,
Soda,
Ammonia,
Oxyd of zinc,
——— manganeſe †,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— ſilver,
——— gold,
——— platinum,
Alumina,
Jargonia ‡ ?
Water,
Silica,
Alcohol.

* *Dr Hope.*

† *Lavoiſier.*

‡ *Vauquelin, Ann. de Chim.* xxii. 208.

Sect. X. *Of Carbonic Acid.*

Carbonic acid is compoſed of carbon and oxygen. According to Lavoiſier's experiments, the proportions are 28 parts of carbon and 72 of oxygen. Mr Prouſt informs us, that there is alſo a *carbonous acid* (H); but with this acid we are not at preſent acquainted, and cannot therefore deſcribe it.

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Diſcovery of carbonic acid.

Paracelſus and Van Helmont were acquainted with the fact, that air is extricated from ſolid bodies during certain proceſſes, and the latter gave to air thus produced the name of *gas*. Boyle called theſe kinds of air *artificial airs*, and ſuſpected that they might be different from the air of the atmoſphere. Hales aſcertained the quantity of air that could be extricated from a great variety of bodies, and ſhewed that it formed an eſſential part of their compoſition. Dr Black proved, that the ſubſtances then called *lime*, *magneſia*, and *alkalies*, are compounds, conſiſting of a *peculiar ſpecies of air*, and pure lime, magneſia, and alkali. To this ſpecies of air he gave the name of *fixed air*, becauſe it exiſted in theſe bodies in a fixed ſtate. This air or gas was afterwards inveſtigated by Dr Prieſtley, and a great number of its properties aſcertained. From theſe properties Mr Keir† firſt concluded that it was an acid; and this opinion was ſoon confirmed by the experiments of Bergman, Fontana, &c. Dr Prieſtley at firſt ſuſpected that this acid entered as an element into the compoſition of atmoſpherical air; and Bergman adopting the ſame opinion, gave it the name of *aerial acid*. Mr Bewdly called it *mephitic acid*, becauſe it could not be reſpired without occaſioning death; and this name was alſo adopted by Morveau. Mr Keir called it *calcareous acid*; and at laſt Mr Lavoiſier, after diſcovering its compoſition, gave it the name of *carbonic acid gas*.

† *Keir's Macquer*, art. *Air.*

The opinions of chemiſts concerning the *compoſition* of carbonic acid have undergone as many revolutions as its name. Dr Prieſtley and Bergman ſeem at firſt to have conſidered it as an element; and ſeveral celebrated chemiſts maintained that it was the acidifying principle. Afterwards it was diſcovered that it was a compound, and that oxygen gas was one of its component parts. Upon this diſcovery the prevalent opinion of chemiſts was, that it conſiſted of oxygen and phlogiſton; and when hydrogen and phlogiſton came (according to Mr Kirwan's theory) to ſignify the ſame thing, it was of courſe maintained that carbonic acid was compoſed of oxygen and hydrogen: and though Mr Lavoiſier demonſtrated, that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; becauſe carbon was itſelf conſidered as a compound, into which a very great quantity of hydrogen entered. But after Mr Lavoiſier had demonſtrated, that the weight of the carbonic acid produced was preciſely equal to the carbon and oxygen employed; after Mr Cavendiſh had diſcovered that oxygen and hydrogen when combined did not form carbonic acid, but water—it was no longer poſſible to heſitate that this acid was compoſed of carbon and oxygen. Accordingly all farther diſpute about it ſeems now at an end. At any rate, as we have already examined the objections that have been made to this concluſion, it would be improper to enter upon them here.

If any thing was ſtill wanting to put this concluſion beyond the reach of doubt, it was to *decompound* carbonic acid, and thus to exhibit its component parts by analyſis as well as ſyntheſis. This has been actually done by the ingenious Mr Tennant. Into a tube of glaſs he introduced a bit of phoſphorus and ſome carbonat of lime. He then ſealed the tube hermetically, and applied heat. Phoſphat of lime was formed, and a quantity of carbon depoſited. Now phoſphat of lime is compoſed of phoſphoric acid and lime; and phoſphoric acid is compoſed of phoſphorus and oxygen. The ſubſtances introduced into the tube were phoſphorus, lime and carbonic acid; and the ſubſtances found in it were phoſphorus, lime, oxygen, and carbon. The carbonic acid, therefore, muſt have been decompoſed, and it muſt have conſiſted of oxygen and carbon. This experiment was repeated by Dr Pearſon, who aſcertained that the weight of the oxygen and carbon were together equal to that of the carbonic acid which had been introduced; and in order to ſhew that it was the carbonic acid which had been decompoſed, he introduced pure lime and phoſphorus; and inſtead of obtaining phoſphat of lime and carbon, he got nothing but

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(H) When there are two acids having the ſame baſe, but containing different quantities of oxygen, they are diſtinguiſhed by their termination. The name of that which contains moſt oxygen ends in *ic*, the other in *ous*. Thus ſulphuric and ſulphurous acids, nitric and nitrous, phoſphoric and phoſphorous, carbonic and carbonous.

but phoſphuret of lime. Theſe experiments were alſo confirmed by Meſſrs Fourcroy, Vauquelin, Sylveſtre, and Broigniart (I)†.

Carbonic acid may be obtained by pouring ſulphuric acid upon chalk, and receiving the product in a pneumatic apparatus.

It is inviſible and elaſtic like common air. It extinguiſhes a candle, and is unfit for reſpiration. It has no ſmell.

Its ſpecific gravity is 0,0018‡; but this varies according to its dryneſs or moiſture.

It reddens the tincture of turnſoil, but no other vegetable colour*.

Atmoſpheric air contains about $\frac{1}{100}$ part of this gas (K).

Water abſorbs it by agitation, or by allowing it to remain long in contact with it. At the temperature of 41° water abſorbs its own bulk of this gas. The ſpecific gravity of water ſaturated with it is 1,0015. This water at the temperature of 35°, has little taſte; but if it be left a few hours in the temperature of 88°, it aſſumes an agreeable acidity, and a ſparkling appearance†.

Ice abſorbs no carbonic acid; and if water containing it be frozen, the whole ſeparates in the act of freezing‡.

This gas alſo ſeparates from water at the boiling temperature‖.

Alcohol and oil of turpentine abſorb double their weight of this gas; olive oil its own bulk. Ether mixes with it in the ſtate of gas§.

Phoſphorus ſuffers no change in this gas except it contains a mixture of oxygen gas¶. It has an affinity for common air. Bergman left a bottle of it uncorked, and found that in a few days it contained nothing but common air. Common air, indeed, has ſo ſtrong an affinity for this gas, that it attracts it from water, as Mr Welter has obſerved*.

It is abſorbed by red hot charcoal, as Morozzo and La Metherie have ſhewn.

It is capable of combining with alkalies, alkaline earths, and alumina, and ſeveral metallic oxyds, and of forming compounds known by the name of *carbonats*. It has no affinity for jargonia, according to Klraproth*; but according to Vauquelin, it has†.

Its affinities, as arranged by Bergman, are as follows:

Barytes,
Lime,
Strontites‡,
Potaſs,
Soda,
Magneſia,
Alumina,
Metallic oxyds, as in *ſulphuric acid*,
Oxygen gas‖,
Water,
Alcohol.

Sect. XI. *Of Acetous Acid.*

Acetous Acid.

Acetous acid or vinegar was known many ages before the diſcovery of any other acid, thoſe only excepted which exiſt ready formed in vegetables. It is mentioned by Moſes, and indeed ſeems to have been in common uſe among the Iſraelites and other eaſtern nations at a very early period.

The methods of procuring, purifying and concentrating this acid have been already given in the articles CHEMISTRY, FERMENTATION, and VINEGAR (*Encycl.*) and cannot therefore be repeated in this place.

It has been aſcertained beyond a doubt, that this acid is compoſed of carbon, hydrogen, and oxygen; but neither the manner in which theſe ſubſtances are combined, nor their proportions, have been accurately aſcertained.

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Lowitz's method of obtaining pure acetous acid.

Acetous acid, as commonly prepared, is very fluid, has a pleaſant ſmell and an acid taſte. It reddens vegetable colours. In this ſtate it is mixed with a great proportion of water; but Mr Lowitz of Peterſburg has diſcovered that it may be obtained in a ſolid cryſtallized form. Of this curious and inſtructive proceſs we ſhall tranſcribe his own account*.

* *Crell's Journal*, i. 242. Eng. tranſl.

"I have long been accuſtomed (ſays he) to prepare concentrated vinegar by congelation in the following manner: I freeze a whole barrel of vinegar as much as poſſible, then diſtil the remaining unfrozen vinegar in a water-bath; by which means I at firſt eſpecially collect the ſpirituous etherial part; the vinegar, which next comes over, I freeze again as much as poſſible, and afterwards purify it by diſtilling it again with three or four pounds of charcoal powder. Thus I never fail to get a very pure ſweet-ſmelling, highly concentrated vinegar; the agreeable odour of which, however, may be ſtill further improved by the addition of a proper quantity of the etherial liquor collected at the beginning of the firſt diſtillation, but which muſt be previouſly dephlegmated by two or three rectifications.

"After the diſtillation in the water-bath was over, that no vinegar might be loſt, I uſed to move the retort, with the charcoal powder which remained in it, to a ſand-bath; and thus I obtained by means of a ſtrong fire, a few ounces more of a remarkably concentrated vinegar, which was of a yellow colour.

"Having collected about ten ounces of this concentrated vinegar, I expoſed it laſt winter in the month of December to a cold equal to —22°; in which ſituation it ſhot into cryſtals from every part. I let what remained fluid drop away from the cryſtals into a baſon placed underneath, firſt in the cold air, and afterwards at the window within doors. There remained in the bottle ſnow-white finely foliated cryſtals, cloſely accumulated one upon the other, and which I at firſt took to be nothing but ice. On placing them upon the warm ſtove, they diſſolved into a fluid which was perfectly as limpid

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(I) Count Mouſſin-Pouſchin having boiled a ſolution of carbonat of potaſs on purified phoſphorus, obtained carbon. This he conſidered as an inſtance of the decompoſition of carbonic acid, and as a confirmation of the experiments related in the text. See *Ann. de Chim.* xxv. 105.

(K) At leaſt near the ſurface of the earth. Lamanon, Monges, and the other unfortunate philoſophers who accompanied La Peyrouſe in his laſt voyage, have rendered it not improbable that at great heights the quantity of this gas is much ſmaller. They could detect none in the atmoſphere at the ſummit of the Peak of Teneriffe. See *Lamanon's Memoir at the end of La Perouſe's Voyage*.

Acetous Acid.

limpid as water, had an uncommonly ſtrong, highly pungent, and almoſt ſuffocating acetous ſmell, and in the temperature of —37° immediately congealed into a ſolid white cryſtallized maſs, reſembling camphor.

“ After I had obſerved that vinegar in this ſtate is of ſuch an extraordinary ſtrength and purity as to be in its higheſt degree of perfection, I took all poſſible pains to find out a method of obtaining all the acetous acid in the ſtate of glacial vinegar.

“To avoid circumlocution, I ſhall denote the ſtrength of each ſort of vinegar which it was neceſſary for me to know in my experiments, by degrees, which I aſcertain in the following manner: *viz.* to one drachm of vinegar I add, drop by drop, a clear ſolution of equal parts of carbonat of potaſs and water, till all at once a cloudineſs or precipitation appears. Although, on the appearance of this ſign, the acid is already ſuperſaturated with the alkali, yet it ſeems to me to be a more accurate teſt for aſcertaining its ſtrength than the ceſſation of efferveſcence; for as the point of ſaturation approaches, the efferveſcence becomes ſo imperceptible, that it is almoſt impoſſible to determine with preciſion when it is really at an end. Now, every five drops of the alkaline ſolution, which I find it neceſſary to add to the vinegar till the precipitation takes place, I reckon as one degree. Thus, for example, if a determinate quantity of vinegar requires 25 drops for that effect, I denote its ſtrength by five degrees. This is about the ſtrength of good diſtilled vinegar.

“ I call that vinegar which, in conſequence of its concentration, is capable of cryſtallizing in a great degree of cold, *cryſtallizable vinegar;* the cryſtals of vinegar, ſeparated after the cryſtallization is completed from the remaining fluid portion, I call *glacial vinegar;* and, laſtly, to the fluid reſiduum I give the name of *mother-ley of vinegar.*

“ From a great number of experiments, I have found that vinegar muſt have at leaſt 24 degrees of concentration before it can be brought to cryſtallize by expoſure to the moſt intenſe cold. Vinegar muſt be of the ſtrength of 42 degrees at leaſt in order to become glacial vinegar; *viz.* in this ſtate of concentration it has the property of cryſtallizing in a degree of cold not exceeding that in which water begins to freeze.

I have found that charcoal, on being diſtilled with vinegar in a water bath, poſſeſſes the ſingular and hitherto unknown property of imbibing a certain quantity of the acetous acid in a very concentrated ſtate, and of retaining it ſo ſtrongly, that the acid cannot be ſeparated from it again, but by the application of a conſiderably greater degree of heat than that of boiling water. Upon this circumſtance is founded the new method which I have diſcovered of concentrating vinegar, ſo as to obtain all its acid in the pureſt ſtate, *viz.* that of a glacial vinegar.

“ Let a barrel of vinegar be concentrated by freezing in the manner above deſcribed, and let the concentrated vinegar thus obtained, free from all inflammable or ſpirituous parts, be put into two retorts: Add to each of them five pounds of good charcoal reduced to a fine powder, and ſubject them to diſtillation in a water bath. When no more drops of vinegar come over, put the diſtilled liquor into two freſh retorts; and after adding five pounds of charcoal powder to each, proceed as before to the diſtillation in a water bath. In the mean while, the two firſt retorts are to be placed in a ſand-bath, that by means of a briſk fire, the cryſtallizable vinegar, which is retained in the apparently dry charcoal powder, may be expelled from it. The heat muſt be ſtrong enough to make the drops follow one another every two ſeconds; and when, in this degree of heat, 20 ſeconds intervene between each drop, the vinegar which has been collected muſt be removed; for what follows, is hardly any thing elſe but mere water. In this manner about ſix ounces and a half of cryſtallizable vinegar, which is generally of the ſtrength of between 36 and 40 degrees, may be collected from each retort. As ſoon as the diſtillation by the water bath in the two retorts is over, the diſtilled liquor is to be poured back again into the firſt retorts upon the charcoal powder, which remains in them, and which has been already uſed; and from each of theſe retorts the remaining cryſtallizable vinegar (which generally amounts to as much as the firſt quantity) is to be abſtracted by diſtillation in a ſand bath. Theſe operations may be alternately repeated till all the acid of the vinegar which had been concentrated by freezing is converted into cryſtallizable vinegar; or until the diſtilled liquor, conſtantly becoming weaker and weaker at every repetition of the diſtillation, comes over at length in the ſtate of mere water, which, with the above mentioned quantity of charcoal powder, generally happens at the fourth or fifth diſtillation. Now, in order to obtain the greateſt part of the pure acid contained in the cryſtallizable vinegar in the form of glacial vinegar, it muſt be ſet to cryſtallize in a great degree of cold; and the mother-ley muſt be afterwards thoroughly drained from the glacial vinegar, by letting it drop from the cryſtals, firſt in the cold, and then in the room before the window. The mother-ley may be rendered further cryſtallizable, by diſtilling it with a little charcoal powder; the weaker part, which comes over firſt, being put aſide. But if a perſon wiſhes to keep the cryſtallizable vinegar for other purpoſes, and without ſeparating any glacial vinegar from it, he muſt diſtil the whole of it again with charcoal powder in a ſand-bath.

“ I have found by accurate experiments, that, by means of this curious proceſs, ten pounds of vinegar concentrated by freezing to the 90th degree, may be made to yield 38 ounces of cryſtallizable vinegar, from which 20 ounces of glacial vinegar may be obtained.

“ What conſtitutes the excellence of this method is, that the concentration and purification are effected by one and the ſame medium, *viz.* the charcoal powder; in conſequence of which, both intentions are fulfilled at the ſame time.

“ Laſt year, after much reflection, I was ſo happy as to find out another very effectual method of ſeparating the acetous acid from the other ſubſtances combined with it, ſo as to obtain it at once in the ſtate of a glacial vinegar of the greateſt poſſible ſtrength. The ſeparating medium which I thought of is ſulphat of potaſs ſuperſaturated with ſulphuric acid; a ſalt in which, conformably to my purpoſe, the ſulphuric acid exiſts in a perfectly dry and dephlegmated ſtate.

“ By means of this ſalt a highly concentrated glacial vinegar may be obtained in the following manner:

“ Let three parts of acetated ſoda, prepared with vinegar diſtilled over charcoal, and evaporated to perfect dryneſs, be melted in a ſtrong heat; then pour it out, and rub it to a very fine powder. Mix this powder very accurately with eight parts of ſuperſaturated ſulphat of potaſs that has been previouſly well dried, and in like manner reduced to a fine powder; put the whole into a retort, and diſtil with a gentle heat, in ſuch manner, that along with the drops ſome vapours alſo may be perceived to come out of the neck of the retort; but by no means ſo that the receiver ſhall be filled with theſe vapours. Notwithſtanding the moderate heat, the vinegar comes over very faſt, and the quantity of glacial vinegar, of the ſtrength of 54 degrees, which is thus obtained, amounts to nearly two parts."

466 tion of atous a- on oer bo- di.

Acetous acid is capable of oxydating iron, zinc, lead, nickel, tin, copper.

It does not act upon gold, ſilver, platinum, mercury, biſmuth, cobalt, antimony, arſenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms compounds known by the name of *acetites*.

467 ffinities.

Its affinities are as follows:

Barytes,
Potaſs,
Soda,
Strontites?
Lime,
Magneſia,
Ammonia,
Oxyd of zinc,
——— mangneſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,
——— gold,
——— platinum,
Alumina †,
Jargonia ?*
Water,
Alcohol.

Sect. XII. *Of Acetic Acid.*

If acetite of copper be diſtilled, an acid comes over of a more pungent ſmell than acetous acid, capable of cryſtallizing, and having a ſtronger affinity for other bodies than acetous acid. It is called *acetic acid*, and is ſuppoſed to contain a larger proportion of oxygen than acetous acid. This additional doſe it is ſuppoſed to receive from the oxyd of copper, which during the proceſs is reduced to the metallic ſtate. It can hardly be doubted that the glacial vinegar of Lowitz, deſcribed in the preceding ſection, is really acetic acid, though it would perhaps be difficult to explain its formation. Its affinities are the ſame with thoſe of the acetous acid.

Sect. XIII. *Of Oxalic Acid.*

Sugar, a well-known ſubſtance extracted from the ſugar-cane, appears to have been uſed in the Eaſt at a very early period; but it made its way weſtward very ſlowly. As a medicine, it is mentioned by Dioſcorides; but it was not in common uſe in Europe till after the 14th century.

468 Compoſition of ſugar.

It has been proved that ſugar is compoſed of oxygen, carbon, and hydrogen. Lavoiſier concluded, from a long ſeries of delicate experiments, that it conſiſts of 8 parts of hydrogen, 64 of oxygen, and 28 of carbon.

469 Diſcovery of oxalic acid.

From ſugar, by a particular proceſs, an acid has been obtained called *oxalic acid*, becauſe it exiſts ready formed, as Scheele has proved, in the *oxalis acetoſella*, or wood ſorrel. At firſt, however, it was called the *acid of ſugar*, or the *ſaccharine acid*.

As the earlieſt and beſt account of the oxalic acid was publiſhed by Bergman, he was for a long time reckoned the diſcoverer of it; but Mr Ehrhart, one of Scheele's intimate friends, informs us, that the world is indebted for its knowledge of this acid to that illuſtrious chemiſt,* and Hermſtadt and Weſtrum aſſign the diſcovery to the ſame author †. The aſſertions of theſe gentlemen, who had the beſt opportunity of obtaining accurate information, are certainly ſufficient to eſtabliſh the fact, that Scheele was the real diſcoverer of oxalic acid.

470 Method of procuring it.

Bergman gives us the following proceſs for obtaining this acid. "Put one ounce of white ſugar powdered into a tubulated retort, with three ounces of ſtrong nitric acid, the ſpecific gravity of which is to that of water as 1,567. When the ſolution is over, during which many fumes of the nitrous acid eſcape, let a receiver be fitted, and the liquor made to boil, by which abundance of nitrous gas is expelled. When the liquor in the retort acquires a reddiſh brown colour, add three ounces more of nitric acid, and continue the boiling till the fumes ceaſe, and the colour of the liquor vaniſhes. Then let the contents of the retort be emptied into a wide veſſel; and, upon cooling, a cryſtallization will take place of ſlender, quadrilateral priſms, which are often affixed to each other at an angle of 45°. Theſe cryſtals, collected and dried on blotting paper, will be found to weigh $1\frac{1}{2}$ dr. 19 gr. By boiling the remaining lixivium with two ounces of nitric acid in the retort, till the red fumes almoſt diſappear, and by repeating the cryſtallization as before, $\frac{1}{2}$ dr. 13 gr. of ſolid acid will be obtained. If the proceſs be repeated once more upon the reſiduum, which has now a glutinous conſiſtence, with the ſucceſſive additions of ſmall quantities of nitric acid, amounting in all to two ounces, a ſaline brown deliqueſcent maſs will be formed, weighing half a dram, of which about a half will be loſt by a farther purification. The cryſtals obtained thus at different times may be purified by ſolution and cryſtallization, and by digeſting the laſt lixivium with ſome nitric acid, and evaporation with the heat of the ſun."

By the ſame proceſs Bergman obtained it from gum arabic, alcohol, and honey; Scheele, Hermſtadt, Weſtrum, Hoffman, &c. from a great variety of other vegetable productions; and Berthollet from a great number of animal ſubſtances.

It is of great conſequence not to uſe too much nitric acid, otherwiſe the quantity of oxalic acid will be diminiſhed; and if a very great quantity of nitric acid be uſed, no oxalic acid will be obtained at all.* On the contrary, if too ſmall a quantity of nitric acid be uſed, the acid obtained will not be the oxalic, but the tartarous †. We think we have obſerved, that a conſiderably larger proportion of oxalic acid may be obtained by pouring nitric acid on ſugar, and allowing theſe ſubſtances to act upon each other while cold. When the proceſs is conducted in that manner, hardly any thing ſeparates but nitrous gas.

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† *avoiſier.*

* *auquelin*, . *de* *n.* xxii. 2.

* *Elwert's Magazine for Apothecaries*, 1785, Part i. p. 54.

† *Keir's Dictionary.*

* *Bergman*

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Its properties.

Oxalic acid is capable of cryſtallization, or rather it is generally obtained in that ſtate. Its cryſtals are quadrilateral priſms, the ends of which often terminate in ridges ‡.

They are ſoluble in their own weight of boiling water: water at the temperature of 65,7° diſſolves half its weight of them. The ſpecific gravity of the ſolution is 1,0593 ||. One hundred parts of boiling alcohol diſſolves 56 parts of theſe cryſtals; but at a mean temperature only 40 parts §. They are not eaſily ſoluble in ether. Fixed and volatile oils diſſolve them, and they may be again obtained by gentle evaporation. Too violent a heat would ſublime the acid itſelf.

Oxalic acid has a very acrid taſte when it is concentrated, but a very agreeable acid taſte when ſufficiently diluted with water ¶.

It changes all vegetable blues except indigo to a red. One grain of cryſtallized acid, diſſolved in 1920 grains of water, reddens the blue paper with which ſugar loaves are wrapt: one grain of it, diſſolved in 3600 gr. of water, reddens paper ſtained with turnſole.* According to Morveau, one part of the cryſtallized acid is ſufficient to communicate a ſenſible acidity to 2633 parts of water †.

Its fixity is ſuch, that none of it is ſublimed when water containing it in ſolution is raiſed to the boiling temperature.

When this cryſtallized acid is expoſed to heat in an open veſſel, there ariſes a ſmoke from it, which affects diſagreeably the noſe and lungs. The reſiduum is a powder of a much whiter colour than the acid had been. By this proceſs it loſes $\frac{3}{10}$ths of its weight; but ſoon recovers them again on expoſure to the air. When diſtilled, it firſt loſes its water of cryſtallization, then liquifies and becomes brown; a little phlegm paſſes over, a white ſaline cruſt ſublimes, ſome part of which paſſes into the receiver; but the greateſt part of the acid is deſtroyed, leaving in the retort a maſs $\frac{1}{50}$th of the whole, which has an empyreumatic ſmell, blackens ſulphuric acid, renders nitric acid yellow, and diſſolves in muriatic acid without alteration. That part of the acid which ſublimes is unaltered. When this acid is diſtilled a ſecond time, it gives out a white ſmoke, which, condenſing in the receiver, produces a colourleſs uncryſtallizable acid, and a dark coloured matter remains behind.* During all this diſtillation a vaſt quantity of elaſtic vapour makes its eſcape. From 279 grains of oxalic acid, Bergman obtained 109 cubic inches of gas, half of which was carbonic acid and half hydrogen. Fontana from an ounce of it obtained 430 cubic inches of gas, one-third of which was carbonic acid, the reſt hydrogen. From theſe facts, it is evident that oxalic acid is compoſed of oxygen, hydrogen, and carbon; but the proportions are ſtill unknown.

When nitric acid is frequently diſtilled off oxalic acid, acetous acid is produced.* The ſulphuric acid, when concentrated, ſeems to produce the ſame effect. Muriatic and acetous acids diſſolve oxalic acid, but without altering it †.

Oxalic acid is capable of oxydating lead, copper, iron, tin, biſmuth, nickel, cobalt, zinc, mangaueſe.

47
Its acti
on oth
bodies.

It does not act upon gold, ſilver, platinum, mercury, arſenic?

Oxalic acid combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms ſalts known by the name of *oxalats*.

47
Its affin

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Strontites ‡,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia || ?
Metallic oxyds as in *ſulphuric acid*,
Water,
Alcohol.

SECT. XIV. *Of Tartarous Acid.*

47
Diſcov
of tart
acid.

TARTAR, or *cream of tartar* as it is commonly called when pure, has occupied the attention of chemiſts for ſeveral centuries. Duhamel and Groſſe, and after them Margraf and Rouelle the Younger, proved, that it was compoſed of an acid united to potaſs; but Scheele was the firſt who obtained this acid in a ſeparate ſtate. He communicated his proceſs for obtaining it to Retzius, who publiſhed it in the Stockholm Tranſactions for 1770. It conſiſted in boiling tartar with lime, and in decompoſing the tartrite of lime thus formed by means of ſulphuric acid.

47
Its pro
ties.

This acid, by a gentle evaporation, yields cryſtals ſo irregular in their figure, that every chemiſt who has treated of this ſubject has given a different deſcription of them. According to Bergman, they generally conſiſt of divaricating lamellæ;* according to Van Packen, they aſſume ofteneſt the form of long pointed priſms †; Spielman and Corvinus ‡ obtained them in groupes, ſome of them lance-ſhaped, others needle formed, others pyramidal. Morveau obtained them needleform §. They do not experience any change in the air; heat decompoſes them. In the open fire they burn without leaving any other reſiduum than a coal, which generally contains a little lime||. In cloſe veſſels, the product is carbonic acid and hydrogen gas¶. If the proper quantity of nitric acid be diſtilled off the cryſtals, they are converted into oxalic acid, and the nitric acid, as uſual, paſſes into the nitrous acid.* Hence it is evident that tartarous acid alſo, like the four former, is compoſed of oxygen, hydrogen, and carbon; but the proportions are equally unaſcertained.

This acid, when in cryſtals, diſſolves readily in water. Bergman obtained a ſolution, the ſpecific gravity of which was 1,230†. Morveau obſerved, however, that cryſtals formed ſpontaneouſly in a ſolution, the ſpecific gravity of which was 1,084.

47
Its act
on oth
bodies

It has a very ſharp acid taſte, and reddens vegetable blues.

Tartarous

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† *Hermſtadt.*

‡ *Bergman*, i. 255.

|| *Ibid.*

§ *Ibid.*

¶ *Ibid.*

* *Ibid.*

† *Encycl. Method.* art. *Acide Saccharin.*

* *Bergman.*

* *Weſtrum.*

† *Bergm*

‡ *Dr E Tranſ.* iv.

|| *Vauq Ann. d Chim.* 208.

* *Berg* iii. 36

† *De Eſſent. Tartar*

‡ *Anal de Tar*

§ *Ency Metho Chim.* 323.

|| *Berg ibid.* ii. 465

¶ *Spie* and *C nus, ib*

* *Her* and *W trum.*

† *Berg* i. 250

Water,
Alcohol.

SECT. XVI. *Of Malic Acid.*

482 Diſcovery of malic acid.

SCHEELE diſcovered a peculiar acid in the juices of ſeveral fruits, which, becauſe it is found moſt abundantly in apples, has been called *malic acid.*

483 Method of obtaining it.

He obtained it by the following proceſs. Saturate the juice of apples with potaſs, and add to the ſolution acetite of lead till no more precipitation enſues. Waſh the precipitate carefully with a ſufficient quantity of water; then pour upon it diluted ſulphuric acid till the mixture has a perfectly acid taſte, without any of that ſweetneſs which is perceptible as long as any lead remains diſſolved in it; then ſeparate the ſulphat of lead, which has precipitated, by filtration, and there remains behind pure malic acid[*].

This acid is contained in the berries of the *barberis vulgaris*, the *ſambucus nigra*, the *prunus ſpinoſa*, the *ſorbus aucuparia*, and the *prunus domeſtica*[†].

If nitric acid be diſtilled with an equal quantity of ſugar, till the mixture aſſumes a brown colour (which is a ſign that all the nitric acid has been abſtracted from it), this ſubſtance will be found of an acid taſte; and after all the oxalic acid which may have been formed is ſeparated by lime-water, there remains another acid, which may be obtained by the following proceſs: Saturate it with lime, and filter the ſolution; then pour upon it a quantity of alcohol, and coagulation takes place. This coagulum is the acid combined with lime. Separate it by filtration, and edulcorate it with freſh alcohol; then diſſolve it in diſtilled water, and pour in acetite of lead till no more precipitation enſues. The precipitate is the acid combined with lead, from which it may be ſeparated by diluted ſulphuric acid. It poſſeſſes all the properties of malic acid[‡]. This acid, therefore, may be obtained from ſugar; and it may be converted into oxalic acid, by diſtilling off it the proper quantity of nitric acid[§].

This acid bears a ſtrong reſemblance to the citric, but differs from it in the following particulars:

484 Its properties.

1. The citric acid ſhoots into fine cryſtals, but this acid does not cryſtallize.

2. The ſalt formed from the citric acid with lime is almoſt inſoluble in boiling water; whereas the ſalt made with malic acid and the ſame baſis is readily ſoluble by boiling water.

3. Malic acid precipitates mercury, lead, and ſilver, from the nitrous acid, and alſo the ſolution of gold when diluted with water; whereas citric acid does not alter any of theſe ſolutions.

4. Malic acid ſeems to have a leſs affinity than citric acid for lime; for when a ſolution of lime in the former acid is boiled one minute with a ſalt formed from volatile alkali and citric acid, a decompoſition takes place, and the latter acid combines with the lime and is precipitated.

485 Its combinations.

The malic acid combines with alkalies, alkaline earths, and alumina, and metallic oxyds, and forms ſalts known by the name of *malats.*

Its affinities have not yet been aſcertained.

SECT. XVII. *Of Lactic Acid.*

IF milk be kept for ſome time it becomes ſour. The acid which then appears in it was firſt examined by Scheele, and found by him to have peculiar properties. It is called *lactic* acid. In the whey of milk this acid is mixed with a little curd, ſome phoſphat of lime, ſugar of milk, and mucilage. All theſe muſt be ſeparated before the acid can be examined. Scheele accompliſhed this by the following proceſs:

486 Method obtainin lactic ac

Evaporate a quantity of ſour whey to an eighth part, and then filtrate it: this ſeparates the cheeſy part. Saturate the liquid with lime-water, and the phoſphat of lime precipitates. Filtrate again, and dilute the liquid with three times its own bulk of water; then let fall into it oxalic acid, drop by drop, to precipitate the lime which it has diſſolved from the lime-water: then add a very ſmall quantity of lime-water, to ſee whether too much oxalic acid has been added. If there has, oxalat of lime immediately precipitates. Evaporate the ſolution to the conſiſtence of honey, pour in a ſufficient quantity of alcohol, and filtrate again; the acid paſſes through diſſolved in the alcohol, but the ſugar of milk and every other ſubſtance remains behind. Add to the ſolution a ſmall quantity of water, and diſtil with a ſmall heat, the alcohol paſſes over, and leaves behind the lactic acid diſſolved in water[*].

This acid is incapable of cryſtallizing: when evaporated to dryneſs, it deliqueſces again in the air[†].

487 Its propc ties,

When diſtilled, water comes over firſt, then a weak acid reſembling the tartarous, then an empyreumatic oil mixed with more of the ſame acid, and laſtly carbonic acid and hydrogen gas—there remains behind a ſmall quantity of coal[‡].

488 Combina tions,

The combinations which this acid forms with alkalies, earths, and metallic oxyds, are called *lactats.*

489 And affi ties.

Its affinities, according to Bergman, are as follows:

Barytes,
Potaſs,
Soda,
Ammonia,
Lime,
Magneſia,
Alumina,
Jargonia[§]?
Metallic oxyds as in *ſulphuric acid.*
Water,
Alcohol.

SECT. XVIII. *Of Saccholactic Acid.*

490 Sugar of milk.

IF a quantity of freſh whey of milk be filtrated, and then evaporated by a gentle fire till it is of the conſiſtence of honey, and afterwards allowed to cool, a ſolid maſs is obtained. If this be diſſolved in water, clarified with the white of eggs, filtrated and evaporated, to the conſiſtence of a ſyrup, it depoſits on cooling a number of brilliant white cubic cryſtals which have a ſweet taſte, and for that reaſon have been called *ſugar of milk.* Fabricius Bartholet, an Italian, was the firſt European who mentioned this ſugar. He deſcribed it in his *Encyclopædia Hermetico dogmatica*, publiſhed at Boulognia in 1619; but it ſeems to have been known in India long before that period.

491 Method obtaining ſaccholactic acid.

After Mr Scheele had obtained oxalic acid from ſugar, he wiſhed to examine whether the ſugar of milk would furniſh the ſame product. Upon four ounces of pure ſugar of milk, finely powdered, he poured 12 ounces of diluted nitric acid, and put the mixture in a large glaſs retort, which he placed in a ſand bath. A violent efferveſcence enſuing, he was obliged to remove the retort from the ſand bath till the commotion ceaſed. He then continued the diſtillation till the mixture became yellow. As no cryſtals appeared in the liquor remaining in the retort, after ſtanding two days he repeated the diſtillation as before, with the addition of eight ounces of nitric acid, and continued the operation till the yellow colour, which had diſappeared on addition of the nitrous acid, returned. The liquor in the retort contained a white powder, and when cold was obſerved to be thick. Eight ounces of water were added to dilute this liquor, which was then filtrated, by which the white powder was ſeparated; which being edulcorated and dried weighed 7$\frac{1}{2}$ dr. The filtrated ſolution was evaporated to the conſiſtence of a ſyrup, and again ſubjected to diſtillation, with four ounces of nitric acid as before; after which, the liquor, when cold, was obſerved to contain many ſmall, oblong, four cryſtals, together with ſome white powder. This powder being ſeparated, the liquor was again diſtilled with more nitric acid as before; by which means the liquor was rendered capable of yielding cryſtals again, and by one diſtillation more with more nitrous acid, the whole of the liquor was converted into cryſtals. Theſe cryſtals, added together, weighed five drams; and were found, upon trial, to have the properties of the oxalic acid.

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[*] *Swediſh Tranſ.* and *Crell's Annals for* 1785.

[†] *Ibid.*

[‡] *Ibid.*

[§] *Hermſtadt, Phyſ. Chem.*

[*] *Scheele, Stockholm Tranſ.* 1780.

[†] *Ibid.*

[‡] *Ibid.*

[§] *Vauque Ann. de Chim.* xxi 208.

Mr Scheele next examined the properties of the white powder, and found it to be an acid of a peculiar nature; he therefore called it the *acid of ſugar of milk*. It is now called the *ſaccholactic acid*.

92 According to Scheele it is ſoluble in 60 parts of its weight of boiling water; but Meſſrs Hermſtadt* and Morveau† found, that boiling water only diſſolved $\frac{1}{80}$th part. It depoſited about $\frac{1}{4}$th part on cooling in the form of cryſtals‡.

The ſolution has an acid taſte, and reddens the infuſion of turnſole§. Its ſpecific gravity at the temperature of 53,7°, is 1,0015||.

When diſtilled, it melts very readily, becomes black, and froths; a brown ſalt ſublimes into the neck of the retort, which has the odour of a mixture of amber and benzoin, having an acid taſte, eaſily ſoluble in alcohol, with greater difficulty in water, and burning in the fire with a flame. There paſſes into the receiver a brown liquid having ſome of this ſalt diſſolved in it: There remains behind a coal¶, which Hermſtadt found to contain a ſmall quantity of lime. Concentrated ſulphuric acid diſtilled on this ſalt becomes black, froths and decompoſes it*.

93 Mr Hermſtadt of Berlin had made ſimilar experiments on ſugar of milk at the ſame time with Scheele, and with ſimilar reſults; but he concluded, that the white powder which he obtained was nothing elſe than oxalat of lime with exceſs of acid, as indeed Scheele himſelf did at firſt. After he became acquainted with Scheele's concluſions, he publiſhed a paper in defence of his own opinion; but his proofs are very far from eſtabliſhing it, or even rendering its truth probable. He acknowledges himſelf, that he has not been able to decompoſe this ſuppoſed ſalt: he allows that it poſſeſſes properties diſtinct from the oxalic acid, but he aſcribes this difference to the lime which it contains; yet all the lime which he could diſcover in 240 grains of this ſalt was only 20 grains; and if the alkali which he employed was a carbonat (as it probably was), theſe 20 muſt be reduced to 11. Now Morveau has ſhewn, that oxalic acid, containing the ſame quantity of lime, exhibits very different properties. Beſides, this acid, whatever it is when united with lime, is ſeparated by the oxalic, and muſt therefore be different from it, as it would be abſurd to ſuppoſe that an acid could diſplace itſelf*. The ſaccholactic acid muſt therefore be conſidered as a diſtinct acid, as it poſſeſſes peculiar properties.

494 Its compounds and affinities.

Its compounds with alkalies, earths, and metallic oxyds, are denominated *ſaccholats*.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Magneſia,
Potaſs,
Soda,
Ammonia,
Alumina,
Jargonia†?
Metallic oxyds as in *ſulphuric acid*,
Water,
Alcohol.

SECT. XIX. *Of Gallic Acid.*

495 Nut galls.

THERE is an excreſcence known by the name of *nut gall*, which grows on ſome ſpecies of oaks. This ſubſtance contains a peculiar acid, called from that circumſtance *gallic acid*, the properties of which were firſt examined with attention by the commiſſioners of the academy of Dijon; and the reſult of their experiments was publiſhed in 1777, in the third volume of their Elements of Chemiſtry. In theſe experiments, however, they employed the infuſion of galls, in which the acid is combined with the tanning principle(M). It was reſerved for Scheele to obtain it in a ſtate of purity.

496 Diſcovery of gallic acid.

He obſerved, in an infuſion of galls made with cold water, a ſediment which proved on examination to have a cryſtalline form, and an acid taſte. By letting an infuſion of galls remain a long time expoſed to the air, and removing now and then the mouldy ſkin which formed on its ſurface, a large quantity of this ſediment was obtained, which being edulcorated with cold water, rediſſolved in hot water, filtrated and evaporated very ſlowly, yielded an acid ſalt in cryſtals as fine as ſand*.

497 Method of obtaining it.

There is a ſhorter method of obtaining this acid in a ſtill purer ſtate than Scheele obtained it.

Pour

* Morveau, Encycl. Method. i. p. 291.

† Vauquelin, Ann. de Chim. xxii. 208.

* Stockholm Tranſ. 1786.

(M) A ſubſtance lately diſcovered by French chemiſts, which exiſts alſo in oak-bark, and every other body which may be ſubſtituted for that bark in the operation of tanning. It reſembles the reſins in many properties; but its diſtinguiſhing property is that of forming with glue a compound inſoluble in water. When a little of the decoction of glue is dropped into an infuſion of nut-galls, a white curdy precipitate is inſtantly ſeen: This is the tanning principle combined with glue. The name *tanning principle* has been applied to it, becauſe *tanning* conſiſts in combining this principle with *ſkins*, by which they are converted into leather.

Pour ſulphuric ether on a quantity of powdered galls, and allow it to remain a few hours; by which time it becomes coloured. Put this tincture into a retort, and diſtil off the ether with a ſmall heat. The reſiduum poſſeſſes the colour and brittleneſs of a reſin, and has all the characters of Rouell's reſiduous-extract; it does not attract moiſture from the atmoſphere. Diſſolve it in its own weight of water, and add ſulphuric acid, drop by drop, till the liquor has become of a manifeſtly acid taſte. It cauſes a white precipitate, which becomes coloured, and is immediately rediſſolved. At the end of ſome hours a reſinous matter will have precipitated. Decant off the fluid, dilute it with half its weight of water, filtrate and evaporate it to $\frac{3}{4}$ths in a moderate heat; add pure barytes, till the liquor is no longer capable of decompoſing muriat of barytes; then filtrate it again: and on evaporation in a moderate heat ſmall white priſmatic cryſtals of gallic acid are formed on the ſides of the veſſel†.

It appears from the experiments of Deyeux, that the ſubſtance extracted from nut-galls by ether does not differ much from the extract by water‡. Probably, then, the only reaſon for employing ether is the ſmall heat neceſſary for evaporating it.

There is ſtill another method of obtaining this acid. Diſtil nut-galls in a ſtrong heat, a white ſubſtance ſublimes, which cryſtallizes in the form of needles: This is gallic acid. If the cryſtals are impure, they may be purified by a ſecond ſublimation: but the heat muſt not be too violent, otherwiſe the cryſtals will melt into a brown maſs*. This proceſs was diſcovered by Scheele.

498
Prouſt's method.

But the moſt elegant method of obtaining gallic acid is that of Mr Prouſt. When a ſolution of muriat of tin is poured into an infuſion of nut-galls, a copious yellow precipitate is inſtantly formed, conſiſting of the tanning principle, combined with the oxyd of tin. After diluting the liquid with a ſufficient quantity of water to ſeparate any portion of this precipitate which the acids might hold in ſolution, the precipitate is to be ſeparated by filtration. The liquid contains gallic acid, muriatic acid, and muriat of tin. To ſeparate the tin, a quantity of ſulphurated hydrogen gas is to be mixed with the liquid. Sulphuret of oxyd of tin is precipitated under the form of a brown powder. The liquid is then to be expoſed for ſome days to the light, covered with paper, till the ſuperfluous ſulphurated hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and put by to cool. Cryſtals of gallic acid are depoſited. Theſe are to be ſeparated by filtration, and waſhed with a little cold water. The evaporation of the reſt of the liquid is to be repeated till all the gallic acid is obtained from it†.

499
Its properties.

The gallic acid thus obtained has a very acid taſte, and reddens vegetable colours. It is ſoluble in $1\frac{1}{2}$ parts of boiling water, and in 12 parts of water at the temperature of the atmoſphere. Alcohol diſſolves one-fourth of its weight of this acid at the temperature of the atmoſphere. When boiling hot it diſſolves a quantity equal to its own weight.

When placed upon burning coals, gallic acid takes fire, and at the ſame time diffuſes a very ſtrong odour, which has ſomething aromatic in it. When ſtrongly heated, it melts, boils, becomes black, is diſſipated, and leaves a quantity of charcoal behind it. When diſtilled, a quantity of oxygen gas is diſengaged, an acid liquor is found in the receiver, with ſome gallic acid, not decompoſed, and there remains in the retort a quantity of carbon. If what has paſſed into the receiver be again diſtilled, more oxygen gas is obtained, ſome gallic acid ſtill ſublimes, and a quantity of carbon remains in the retort. By repeated diſtillations, the whole of the acid may be decompoſed. This decompoſition may be more eaſily accompliſhed by diſtilling repeatedly a ſolution of gallic acid in water. The products are oxygen gas, charcoal, and an acid liquor.

5
Its co
ſition.

From theſe experiments, Mr Deyeux, who performed them, has concluded, that gallic acid is compoſed of oxygen, and a much larger proportion of carbon than enters into the compoſition of carbonic acid. But this concluſion is not warranted by the analyſis; for Mr Deyeux did not find that the quantity of oxygen gas and carbon obtained was equal to that of the gallic acid decompoſed: and in the acid liquor which came over, there evidently exiſted a quantity of water, which doubtleſs was formed during the diſtillation. Scheele, by treating gallic acid with nitric acid in the uſual manner, converted it into oxalic acid. Now it is certain, that oxalic acid contains hydrogen as well as carbon. It cannot be doubted, then, that gallic acid is compoſed of oxygen, hydrogen, and carbon, in proportions not yet aſcertained. But Mr Deyeux has proved, that the quantity of carbon is very great, compared with that of the hydrogen.

Gallic acid combines with alkalies, earths, and metallic oxyds, and forms compounds, known by the name of *gallats*.

Its affinities have not yet been determined; but oxyd of iron ſeems to have a ſtronger affinity for it than for any other ſubſtance; for gallic acid is capable of taking it from every other acid. In conſequence of this property, the infuſion of galls is employed to detect the preſence of iron in any liquid. As ſoon as it is poured in, if iron be preſent, a black or purple colour is produced.

SECT. XX. *Of Benzoic Acid.*

50
Benz

BENZOIN or *benjamin* (as it is ſometimes called) is a kind of reſin brought from the Eaſt Indies; obtained, according to Dr Dryander, from the ſtyrax benzoe, a tree which grows in the iſland of Sumatra. This ſubſtance conſiſts partly of a peculiar acid, deſcribed as long ago as 1608 by Blaiſe de Vigenere, in his Treatiſe on Fire and Salt, under the name of *flowers of benzoin*, becauſe it was obtained by ſublimation. This acid, which is now called *the benzoic acid*, may be ſublimed from benzoin by heat; or it may be obtained by Scheele's proceſs, which has been deſcribed in the article CHEMISTRY *(Encycl.)*

50
Proper
of benz
acid.

Benzoic acid has little or none of the peculiar odour which diſtinguiſhes benzoin. Its taſte is not acid, but ſweetiſh and very pungent*. It hardly affects the infuſion of violets; but it reddens that of turnſole, eſpecially if that infuſion be hot†. Heat volatilizes this acid, and makes it give out a ſtrong odour, which excites coughing. When expoſed to the heat of the blow-pipe in a ſilver ſpoon, it melts, becomes as fluid as water, and evaporates without taking fire. It only burns when in contact with flame, and then it leaves no

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† *Mr J. J. Dizé, Jour. de Phyſ.* Dec. 1791.

‡ *Ann. de Chim.* xvii. 8.

* *Ibid.*

† *Ibid.* xxv. 225.

* *Mor Encycl. Metho Chimie,* 44.

† *Licht ſtein.*

S cinic .cid.

no reſiduum behind. When thrown upon burning coals, it riſes in a white ſmoke. When allowed to cool after being melted, it hardens, and a radiated cruſt forms on its ſurface‡.

It ſuffers no other alteration in the air than loſing the little of the odour of benzoin which remained to it*.

Cold water diſſolves no ſenſible quantity of it; but it is ſoluble enough in hot water: 480 grains of boiling water diſſolve 20 grains of it; 19 of theſe are depoſited, when the water cools, in long, ſlender, flat, feather-like cryſtals†.

Concentrated ſulphuric acid diſſolves it without heat or any other change, except becoming ſomewhat brown: when water is poured into the ſolution, the benzoic acid ſeparates and coagulates on the ſurface without any alteration‡. Nitric acid preſents preciſely the ſame phenomena, and alſo the ſulphurous and nitrous acids. Neither the muriatic, the oxy-muriatic, nor the phoſphoric acids diſſolve it. The acetous, formic, and ſebacic acids, when hot, diſſolve it preciſely as water does; but it cryſtallizes again when theſe acids cool ||.

Alcohol diſſolves it copiouſly, and lets it fall on the addition of water*.

Little is known reſpecting its baſe.

503 It ombi- ons and ities.

It combines with alkalies, earths, and metallic oxyds, and forms ſalts, known by the name of *benzoats*.

Its affinities, from the experiments of Trommſdorf, appear to be as follows:

White oxyd of arſenic,
Potaſs,
Soda,
Ammonia,
Barytes,
Lime,
Magneſia,
Alumina,
Jargonia ‡?
Water,
Alcohol.

Sect. XXI. *Of Succinic Acid.*

504 mber.

Amber is a well-known brown, tranſparent, inflammable body, pretty hard, and ſuſceptible of poliſh, found at ſome depth in the earth, and on the ſea-coaſt of ſeveral countries. It was in high eſtimation among the ancients both as an ornament and a medicine.—When this ſubſtance is diſtilled, a volatile ſalt is obtained, which is mentioned by Agricola under the name of *ſalt of amber*; but its nature was long unknown. Boyle was the firſt who diſcovered that it was an acid*. From *ſuccinum*, the Latin name of amber, this acid has received the appellation of *ſuccinic acid*.

505 thod of aining cinic d.

It is obtained by the following proceſs: Fill a retort half way with powdered amber, and cover the powder with a quantity of dry ſand; lute on a receiver, and diſtil in a ſand-bath without employing too much heat. There paſſes over firſt an inſipid phlegm; then a weak acid, which, according to Scheele, is the acetous†; then the ſuccinic acid attaches itſelf to the neck of the retort; and if the diſtillation be continued, there comes over at laſt a thick brown oil, which has an acid taſte.

The ſuccinic acid is at firſt mixed with a quantity of oil. Perhaps the beſt method of purifying it is that recommended by Pott, to diſſolve it in hot water, and to put upon the filter a little cotton, previouſly moiſtened with oil of amber; this ſubſtance retains moſt of the oil, and allows the ſolution to paſs clear. The acid is then to be cryſtallized by a gentle evaporation. And this proceſs is to be repeated till the acid be quite pure.

506 Its properties,

The cryſtals are white, ſhining, and of a foliated triangular priſmatic form: they have an acid taſte, but are not corroſive: they redden tincture of turnſole; but have little effect on that of violets.

They ſublime when expoſed to a conſiderable heat, but not at the heat of a water-bath. In a ſand-bath they melt, and then ſublime and condenſe in the upper part of the veſſel; but the coal which remains ſhews that they are partly decompoſed*.

One part of this acid diſſolves in 96 parts of water at the temperature of 50°, according to Spielman‡, in 24 parts at the temperature of 52°, and in 2 parts of water at the temperature of 212°, according to Stockar de Neuforn†; but the greateſt part cryſtallizes as the water cools. According to Roux, however, it ſtill retains more of the acid than cold water is capable of diſſolving‡.

240 grains of boiling alcohol diſſolve 177 of this acid; but cryſtals again ſhoot as the ſolution cools*.

507 Combinations and affinities.

The combinations of this acid are called *ſuccinats*.

Its component parts are ſtill unknown.

Its affinities, according to Morveau, are as follows:

Barytes,
Lime,
Potaſs,
Soda,
Ammonia,
Magneſia,
Alumina,
Jargonia †?
Metalic oxyds, as in *ſulphuric acid*,
Water,
Alcohol.

Sect. XXII. *Of Camphoric Acid.*

508 Camphor.

Camphor is a well-known white cryſtalline ſubſtance, of a ſtrong taſte and ſmell, obtained from a ſpecies of laurel in the Eaſt Indies; and Mr Prouſt has ſhown that ſeveral volatile oils contain a conſiderable quantity of it*. It is ſo volatile, that it cannot be melted in open veſſels, and ſo inflammable, that it burns even on the ſurface of water.

When camphor is ſet on fire in contact with oxygen gas, it burns with a very brilliant flame; much caloric is diſengaged, water is formed, the inner ſurface of the veſſel is covered with a black matter, which is undoubtedly carbon, and a quantity of carbonic acid gas is alſo produced.† Hence it follows, that it is compoſed of hydrogen and carbon, at leaſt principally.

If one part of camphor and ſix parts of pulveriſed clay be mixed together, by means of alcohol, in a mortar, the mixture made up into balls, and when dry put into a retort, and diſtilled by a moderate heat—a quantity of oil comes over, and there remains in the retort a black ſubſtance, which conſiſts of the clay intimately mixed with a quantity of carbon. If the fire be not cautiouſly managed, a quantity of camphor alſo ſublimes.

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‡ *In.*

* *orveau, ibid*

† *hten- ſtei*

‡ *uque- li Ann. de C. .* xxii. 2

* *oyle a- b ged by S w,* iii. .

† *Bergman's tes on effier.*

* *Pott.*

‡ *Inſt. Chem.* § xii.

† *De Succino.*

‡ *Morveau, ibid*, p. 72.

* *Wenzel.*

† *Vauquelin, Ann. de Chim.* xxii. 208.

* *Ann. de Chim.* iv. 179.

† *La Grange, Ann. de Chim.* xxiii. 153.

Camphoric Acid.

limes. By this proceſs, camphor is decompounded, and ſeparated into oil and carbon.

122,248 parts of camphor
produced 45,856 parts of oil
and 30,571 of carbon.

Total 76,427
Loſs 45,821

Carbonated hydrogen gas and carbonic acid were alſo formed‡.

509
Oil of camphor.

The oil obtained has the following properties:

It has a ſharp cauſtic taſte, and leaves upon the tongue a ſenſe of coldneſs. It has an aromatic odour, approaching to that of thyme or roſemary. Its colour is a golden yellow.

When expoſed to the air, it partly evaporates, and there remains a thick brown matter with a ſharp bitteriſh taſte, which at laſt alſo evaporates.

With alkalies, it forms a ſoap, which poſſeſſes all the characters of ſoaps made with volatile oils.

Alcohol diſſolves it entirely; and when water is added to the ſolution it becomes milky, but no precipitate is produced‡.

Theſe properties ſhow that this is a volatile oil, and conſequently it is probable that camphor is compoſed of volatile oil and carbon.

510
Camphoric acid.

Mr Koſegarten, by diſtilling nitric acid off camphor eight times ſucceſſively, obtained an acid in cryſtals*, to which the name of *camphoric acid* has been given.

His experiments have been repeated by Mr Bouillon La Grange. He mixed together 122,284 parts of camphor with 489,136 parts of nitric acid of the ſpecific gravity 1,33, and diſtilled them. Much nitrous and carbonic acid gas were diſengaged, and part of the camphor was ſublimed; but part was converted into an acid. He returned the ſublimed camphor into the retort, poured on it the ſame quantity of nitric acid as at firſt, and diſtilled again. This proceſs he repeated till the whole camphor was acidified†. The quantity of camphoric acid obtained amounted to 53,498. The quantity of nitric acid was 2114,538.

511
Its properties.

Camphoric acid thus obtained is in ſnow-white cryſtals, of the form of parallelopipedons*.

Theſe cryſtals effloreſce in the air ‡.

Camphoric acid has a ſlightly acid bitter taſte, and a ſmell like that of ſaffron.

It reddens vegetable colours.

It is ſoluble in 200 parts of cold water, according to Koſegarten; in 96 parts of water at the temperature of 60°, according to La Grange. Boiling water diſſolves $\frac{1}{12}$th of its weight§.

According to Koſegarten, it is inſoluble in alcohol; according to La Grange, alcohol diſſolves it, and when the ſolution is left in contact with the air of the atmoſphere, the acid cryſtallizes. It is not precipitated from its ſolution in alcohol by the addition of water*.

When this acid is placed on ignited coals, it emits a denſe aromatic fume, and is entirely diſſipated. By a gentler heat, it melts, and is ſublimed. If it be put into a heated porcelain tube, and oxygen gas be paſſed through it, the acid does not undergo any change, but is ſublimed.

By mere diſtillation, it firſt melts and then ſublimes; by which proceſs its properties are in ſome reſpect changed. It no longer reddens the tincture of turnſol, but acquires a briſk aromatic ſmell; its taſte becomes leſs penetrating, and it is no longer ſoluble either in water or the ſulphuric and muriatic acids. Heated nitric acid turns it yellow and diſſolves it. Alcohol likewiſe diſſolves it; and if this ſolution be left in contact with the air of the atmoſphere, it cryſtallizes.

Camphoric acid does not produce any change in ſulphur; alcohol and the mineral acids totally diſſolve it; and ſo likewiſe do the volatile and the fat oils.

Camphoric acid does not precipitate lime from lime-water. It produces no change on the ſolution of indigo in ſulphuric acid.

51
Its con
nation
affiniti

It forms combinations with the alkalies, earths, and metallic oxyds, which are called *camphorats*.

Its affinities, as far as aſcertained by La Grange, are as follows*.

Lime,
Potaſs,
Soda,
Barytes,
Ammonia,
Alumina,
Magneſia.

Sect. XXIII. *Of Suberic Acid.*

51
Diſcov
of ſub
acid.

Cork, a ſubſtance too well known to require any deſcription, is the bark of a tree which bears the ſame name. By means of nitric acid, Brugnatelli converted it into an acid†, which has been called the *ſuberic acid*, from *Suber*, the Latin name of the cork tree. Several chemiſts affirmed that this acid was the oxalic, becauſe it poſſeſſed ſeveral properties in common with it. Theſe aſſertions induced Buillon La Grange to undertake a ſet of experiments on ſuberic acid. Theſe experiments, which have been publiſhed in the 23d volume of the *Annales de Chimie*, completely eſtabliſh the peculiar nature of ſuberic acid, by ſhewing that it poſſeſſes properties different from thoſe of every other acid.

51
Metho
prepar
it.

To prepare it, a quantity of ſound cork grated down ſmall is to be put into a retort, ſix times its weight of nitric acid of the ſpecific gravity 1,261 poured upon it, and the mixture diſtilled by means of a gentle heat. Red vapours are immediately diſcharged; the cork ſwells up and becomes yellow, and as the diſtillation advances, it ſinks to the bottom, and its ſurface remains frothy. If that froth does not form properly, it is a proof that ſome part of the cork has eſcaped the action of the acid. In that caſe, after the diſtillation is pretty far advanced, the acid which has paſſed into the receiver is to be poured back into the retort, and the diſtillation continued till no more red vapours can be perceived; and then the retort is to be immediately taken out of the ſand-bath, otherwiſe its contents would become black and adhere to it. While the matter contained in the retort is hot, it is to be poured into a glaſs veſſel, placed upon a ſand-bath over a gentle fire, and conſtantly ſtirred with a glaſs rod. By this means it becomes gradually thick. As ſoon as white vapours, exciting a tickling in the throat, begin to diſengage themſelves, the veſſel is removed from the bath, and the maſs continually ſtirred till it is almoſt cold.

By this means an orange coloured maſs is obtained of the conſiſtence of honey, of a ſtrong and ſharp odour while hot, but having a peculiar aromatic ſmell when cold.

On

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‡ *Ibid.*

‡ *Ann. de Chim.* xxiii. 159.

* *Koſegarten, de Camphora, &c.* 1785.

† *Ann. de Chim. ibid.*

* *Koſegarten.*

‡ *La Grange.*

§ *Koſegarten.*

* *Bouillon La Grange, Ann. de Chim.* xxvii. 40.

* *Ann. Chim.* 21.

† *Crell Annals* 1787.

Barytes,
Potaſs,
Soda,
Lime,
Ammonia,
Magneſia,
Alumina.*

* Ann. de Chim. xxiii. 42.

518 Its compoſition.

Mr Buillon La Grange, to whom we are indebted for all the facts relative to this acid, ſuppoſes that it is compoſed of oxygen, hydrogen, and carbon: but Mr Jameſon, in conſequence of the reſult of a ſeries of experiments which he made on charcoal, has been led to ſuſpect that it conſiſts entirely of carbon and oxygen. He found that, by the action of nitric acid upon charcoal, a brown, bitter, deliqueſcent maſs was formed, ſoluble in water, alcohol, and alkalies, and which emitted, particularly when heated, a very fragrant odour. This matter was more or leſs ſoluble in water according to the time that it had been expoſed to the action of the acid. When the nitric acid uſed was concentrated, and conſiderable in quantity, part of the charcoal was converted into an acid, which poſſeſſed the characters of the ſuberic †.

† Jameſon's Mineralogy of Shetland and Arran, p. 167.

Theſe facts are curious, and may extend our knowledge of the nature of vegetable acids, but they are inſufficient to prove the abſence of hydrogen in ſuberic acid, becauſe charcoal cannot eaſily be procured perfectly free from hydrogen, and becauſe ſeveral of the properties of ſuberic acid indicate the preſence of hydrogen in it, its becoming brown, for inſtance, when expoſed to the light. Mr Jameſon has obſerved, that the acid which exiſts ready formed in peat poſſeſſes the properties of ſuberic acid.

Sect. XXIV. *Of Laccic Acid.*

519 Diſcovery of white lac.

About the year 1786, Dr Anderſon of Madras mentioned in a letter to the governor and council of that place, that neſts of inſects, reſembling ſmall cowry ſhells, had been brought to him from the woods by the natives, who eat them with avidity. Theſe ſuppoſed neſts he ſoon afterwards diſcovered to be the coverings of the females of an undeſcribed ſpecies of coccus, which he ſhortly found means to propagate with great facility on ſeveral of the trees and ſhrubs growing in his neighbourhood (R).

On examining this ſubſtance, which he called *white lac*, he obſerved in it a very conſiderable reſemblance to bees wax; he noticed alſo, that the animal which ſecretes it provides itſelf by ſome means or other with a ſmall quantity of honey, reſembling that produced by our bees; and in one of his letters he complains, that the children whom he employed to gather it were tempted by its ſweetneſs to eat ſo much of it as materially to reduce the produce of his crop. Small quantities of this matter were ſent into Europe in 1789, both in its natural ſtate and melted into cakes; and in 1793 Dr Pearſon, at the requeſt of Sir Joſeph Banks, undertook a chemical examination of its qualities, and his experiments were publiſhed in the Philoſophical Tranſactions for 1794.

52c Its anal

A piece of white lac, from 3 to 15 grains in weight, is probably produced by each inſect. Theſe pieces are of a grey colour, opaque, rough, and roundiſh. When white lac was purified by being ſtrained through muſlin, it was of a brown colour, brittle, hard, and had a bitteriſh taſte. It melted in alcohol, and in water of the temperature of 145°. In many of its properties it reſembles bees wax, though it differs in others; and Dr Pearſon ſuppoſes that both ſubſtances are compoſed of the ſame ingredients, but in different proportions.

Two thouſand grains of white lac were expoſed in ſuch a degree of heat as was juſt ſufficient to melt them. As they grew ſoft and fluid, there oozed out 550 grains of a reddiſh watery liquid, which ſmelled like newly baken bread (S). To this liquid, Dr Pearſon has given the name of *laccic acid* †.

† Pearſ. Tranſ. the Che Nomenc ture.

521 Proper of lacc acid.

It poſſeſſes the following properties:

It turns paper ſtained with turnſole to a red colour.

After being filtered, it has a ſlightly ſaltiſh taſte with bitterneſs, but is not at all ſour.

When heated, it ſmells preciſely like newly baken hot bread.

On ſtanding, it grows ſomewhat turbid, and depoſits a ſmall quantity of ſediment.

Its ſpecific gravity at the temperature of 60° is 1,025.

A little of it having been evaporated till it grew very turbid, afforded on ſtanding ſmall needle ſhaped cryſtals in mucilaginous matter.

Two hundred and fifty grains of it were poured into a very ſmall retort and diſtilled. As the liquor grew warm, mucilage like clouds appeared; but as the heat increaſed they diſappeared again. At the temperature of 200°, the liquor diſtilled over very faſt: A ſmall quantity of extractive matter remained behind. The diſtilled liquor while hot ſmelled like newly baken bread, and was perfectly tranſparent and yellowiſh. A ſhred of paper ſtained with turnſole, which had been put into the receiver, was not reddened; nor did another which had been immerſed in a ſolution of ſulphat of iron, and alſo placed in the receiver, turn to a blue colour upon being moiſtened with the ſolution of potaſs (T).

About one hundred grains of this diſtilled liquid being evaporated till it grew turbid, after being ſet by for a night, afforded acicular cryſtals, which under a lens appeared in a group not unlike the umbel of parſley. The whole of them did not amount to the quarter of a grain. They taſted only bitteriſh.

Another 100 grains being evaporated to dryneſs in a very low temperature, a blackiſh matter was left behind, which did not entirely diſappear on heating the ſpoon

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(R) The Chineſe collect a kind of wax, which they call *pe-la*, from a coccus, depoſited for the purpoſe of breeding on ſeveral ſhrubs, and manage it exactly as the Mexicans manage the cochineal inſect. It was the knowledge of this that induced Dr Anderſon to attempt to propagate his inſect.

(S) The ſame liquid appears on preſſing the crude lac between the fingers; and we are told, that when newly gathered it is replete with juice.

(T) A proof that the acid was not the pruſſic.

Laccic Acid.

ſpoon containing it very hot in the naked fire; but on heating oxalic acid to a much leſs degree, it evaporated and left not a trace behind.

Carbonat of lime diſſolved in this diſtilled liquor with effervescence. The ſolution taſted bitteriſh, did not turn paper ſtained with turnſole red, and on adding to it carbonat of potaſs a copious precipitation enſued. A little of this ſolution of lime and of alkali being evaporated to dryneſs, and the reſiduum made red hot, nothing remained but carbonat of lime and carbonat of potaſs.

This liquid did not render nitrat of lime turbid, but it produced turbidneſs in nitrat and muriat of barytes.

To five hundred grains of the reddiſh-coloured liquor obtained by melting white lac, carbonat of ſoda was added till the effervescence ceaſed, and the mixture was neutraliſed; for which purpoſe three grains of the carbonat were neceſſary. During this combination a quantity of mucilaginous matter, with a little carbonat of lime, was precipitated. The ſaturated ſolution being filtrated and evaporated to the due degree, afforded on ſtanding deliqueſcent cryſtals, which on expoſure to fire left only a reſiduum of carbonat of ſoda.

Lime-water being added to this reddiſh-coloured liquor produced a light purple turbid appearance; and on ſtanding there were clouds juſt perceptible.

Sulphuret of lime occaſioned a white precipitation, but no ſulphurated hydrogen gas was perceptible by the ſmell.

Tincture of galls produced a green precipitation.

Sulphat of iron produced a purpliſh colour, but no precipitation; nor was any precipitate formed by the addition firſt of a little vinegar, and then of a little potaſs, to the mixture.

Acetite of lead occaſioned a reddiſh precipitation, which rediſſolved on adding a little nitric acid.

Nitrat of mercury produced a whitiſh turbid liquor.

Oxalic acid produced immediately the precipitation of white acicular cryſtals, owing probably to the preſence of a little lime in the liquid.

Tartrite of potaſs produced a precipitation not unlike what takes place on adding tartarous acid to tartrite of potaſs (u); but it did not diſſolve again on adding potaſs.

Such were the properties of this acid diſcovered by Dr Pearſon. Its deſtructibility by fire, and its affording carbon, diſtinguiſh it from all the acids deſcribed in this article before the acetous; and its peculiar ſmell when heated, its precipitating tartrite of potaſs without forming tartar, its bitteriſh taſte, and its being converted into vapour at the temperature of 200°, diſtinguiſh it from all the acids hitherto examined*.

* Phil. Tran. 1794. 383.

SECT. XXV. *Of Pyromucous Acid.*

522
Method of obtaining Pyromucous acid.

PYROMUCOUS (v) acid is procured by diſtilling ſugar or any of the ſweet juices. As they foam very much, the retort ſhould be large, and ſeven-eighths of it empty. A prodigious quantity of carbonic acid and carbonated hydrogen gas is diſengaged: A very thin light coal remains behind in the retort. Morveau found the glaſs of the retort attacked. The quantity of ſugar diſtilled was 2304 grains; the coal weighed 982 grains. There were 428 grains of a brown liquor in the receiver, conſiſting moſtly of an acid phlegm. This rediſtilled gave 313 grains of a liquor almoſt limpid, the ſpecific gravity of which was 1,0115 at the temperature of 77°. It reddened blue paper. This acid may be concentrated by freezing, or by combining it with ſome baſe, potaſs for inſtance, and decompoſing the compound by a ſtronger acid, as, for example, the ſulphuric.

Pyromucous Acid.

523
Its properties,

It has a very ſharp taſte. When expoſed to heat in open veſſels it evaporates, leaving a brown ſpot. Diſtilled in cloſe veſſels, it leaves charcoal behind it.

It does not diſſolve gold as Schrickel and Lemery and ſeveral other chemiſts affirmed.

It does not attack ſilver nor mercury, nor even their oxyds†. It corrodes lead, and forms ſtyptic and long cryſtals. Copper forms with it a green ſolution: With iron it forms green cryſtals; with antimony and zinc greeniſh ſolutions.

† *Schrickel.*

524
Combinations and affinities.

The compounds which it forms are called *pyromucites*.

Its affinities, according to Morveau, are as follows:

Potaſs,
Soda,
Barytes,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia†,
Metallic oxyds as in ſulph. acid,
Water,
Alcohol.

† *Vauquelin, Ann. de Chim.* xxii. 208.

SECT. XXVI. *Of Pyro-lignous Acid.*

525
Method of obtaining pyro-lignous acid.

IT is well known that the ſmoke of burning wood is exceedingly offenſive to the eyes: And chemiſts have long ago obſerved, that an acid might be obtained by diſtilling wood.

It is to Mr Goettling, however, and to the Dijon academicians, who repeated his experiment, that we are indebted for what knowledge we poſſeſs of the peculiar properties of this acid, which, becauſe it is obtained from wood by means of fire, has been called *the pyro-lignous acid* (w). It appears to be the ſame from whatever kind of wood it is obtained.

Mr Goettling filled an iron retort with pieces of birch tree bark, and obtained by diſtillation a thick, brown, very empyreumatic acid liquor. This liquor he allowed to remain at reſt for three months, and then ſeparated from it a quantity of oil which had riſen to the top. By diſtilling this liquor again, and then ſaturating it with potaſs, and evaporating it to dryneſs, he obtained a brown ſaline maſs; which, by being rediſſolved in water, and evaporated, yielded greyiſh white cryſtals: Theſe cryſtals were compoſed of pyro-lignous acid

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(u) On this addition, tartar, or acidulated tartrite of potaſs, is formed, which precipitates, becauſe it is very little ſoluble in water. The addition of potaſs diſſolves it again.

(v) Morveau called this acid *ſyrupous* acid.

(w) Goettling called it *ligneous acid.*

50,19 oxygen
13,94 hydrogen,
35,87 carbon.

100,00

Theſe numbers can only be conſidered as approximations to the truth; for the object of Dr Higgins was not to aſcertain the proportions of the ingredients which compoſe acetous acid; and therefore his experiments were not conducted with that rigid accuracy which would have been neceſſary for that purpoſe.

It is extremely probable, that during the acetous fermentation, or the converſion of alcohol into acetous acid, a quantity of water is formed*; and it is certain that oxygen is abſorbed. It follows from this, that acetous acid contains more carbon and leſs hydrogen than alcohol. Now we have reaſon, from Lavoiſier's experiments, to believe, that alcohol is formed of

51,72 oxygen,
18,40 hydrogen,
29,88 carbon.

Lavoiſier ſuppoſes that this acid contains alſo azot.

3. Acetic acid is ſuppoſed to conſiſt of the ſame baſe with acetous acid, combined with a larger proportion of oxygen; we would rather ſay, that it is acetous acid combined with oxygen.

4. When oxalic acid is diſtilled with ſix times its weight of ſulphuric acid, the products are acetous acid, ſulphurous acid, carbonic acid gas, and ſulphuric acid remains in the retort†. Hence it follows, that oxalic acid contains more carbon than acetous acid; but that it is compoſed of the ſame ingredients. It has been ſuppoſed, that oxalic acid is compoſed of ſugar and oxygen. Now ſugar, according to Lavoiſier, is compoſed of

Hydrogen, - - - - -	8
Oxygen, - - - - -	64
Carbon, - - - - -	28

Theſe proportions are rather unfavourable to that notion; at leaſt if any dependence can be put in the compoſition of acetous acid as deduced from the experiments of Dr Higgins.

5. Hermſtadt diſſolved four ounces of tartarous acid in 16 ounces of water, and kept the ſolution in a veſſel covered with paper in a warm place. In three months the taſte of the ſolution was changed, and the air in the upper part of the veſſel was found to be carbonic acid. In ſix months the ſolution was converted into acetous acid. It follows from this experiment, that tartarous acid contains more carbon than acetous acid, and that their ingredients are the ſame. If any doubts ſhould remain, the following experiment is ſufficient to remove them. Weſtrum mixed ſtrong ſulphuric acid with tartarous acid, and added manganeſe; acetous acid was produced, and a great quantity of carbonic acid gas was diſengaged. When nitric acid is diſtilled off tartarous acid, it is converted into oxalic acid, as Scheele firſt proved. Hence it has been ſuppoſed by ſome, that oxalic acid differs from tartarous merely in containing more oxygen: but this is very far indeed from being proved. According to Haſſenfratz, tartarous acid contains a conſiderable quantity of azot.

6. When citrat of lime is allowed to remain in a bottle ſlightly corked along with a little alcohol, the citric acid is gradually converted into acetous acid‡. Weſtrum converted it into oxalic acid by means of nitric acid.

7. Malic acid was converted into oxalic by means of nitric acid by Scheele. It has been ſuppoſed to contain more oxygen than oxalic acid. Some of it is always formed during the common proceſs of converting ſugar into oxalic acid. Were we to judge from an experiment, which, however, was not performed with ſufficient accuracy, we would conclude that the baſe of malic acid is gum; for by diſtilling two parts of weak nitric acid off one part of gum in a very ſmall heat, we obtained a quantity of acid more in weight than the gum, which exhibited ſeveral of the diſtinguiſhing properties of malic acid. It was exceedingly light, white, and ſpongy, and attracted water very quickly from the atmoſphere, and could not afterwards be brought by evaporation to its former ſtate.

8. Scheele converted lactic acid into acetous by mere expoſure to the atmoſphere, and found that a quantity of carbonic acid was diſengaged. Hence this acid is merely the acetous with a ſmaller proportion of carbon.

9. The gallic acid, we have ſeen, contains more carbon than any of the others.

10. Nothing is known concerning the compoſition of the benzoic and ſuccinic acids. Hermſtadt ſays he converted benzoic acid to oxalia by means of nitric acid: but Morveau did not obſerve that any change was produced.

11. The baſe of camphoric is probably camphor.

Though theſe eighteen are the only acids which have hitherto been examined with attention, it cannot be doubted that the number of vegetable acids, either exiſting naturally, or at leaſt capable of being formed by art, is conſiderably greater. Morveau has lately aſcertained, that the red colours of flowers are owing to acids: This had already been conjectured by Linnæus.

SECT. XXVIII. *Of Pruſſic Acid.*

532
Diſcovery of Pruſſian blue.

About the beginning of the preſent century, Dieſbach, a chemiſt of Berlin, wiſhing to precipitate a ſolution of cochineal mixed with a little alum and ſulphat of iron, borrowed from Dippel ſome potaſs, from which that chemiſt had *diſtilled* ſeveral times his *animal oil.* On pouring in the potaſs, Dieſbach was ſurprized to ſee, inſtead of the red precipitate which he had expected, a beautiful blue powder falling to the bottom of the veſſel. By reflecting on the materials which he had employed, he eaſily diſcovered the method of procuring the blue powder at pleaſure*. This powder was called *Pruſſian blue*, from the place where it was diſcovered. It was announced in the Berlin Memoirs for 1710; but the proceſs was concealed, becauſe it had become a lucrative article of commerce. A method of preparing it, however, was publiſhed by Woodward in the Philoſophical Tranſactions for 1724, which he ſaid he had got from one of his friends in Germany. This method was as follows: Detonate together 4 ounces of nitre and as much tartar, in order to procure an extemporaneous alkali; then add 4 ounces of dried bullock's blood, mix the ingredients well together, and put them into a crucible covered with a lid, in which there is a ſmall hole; calcine with a moderate fire till the blood emits no more ſmoke or flame capable of blackening any white body expoſed

533
Method of preparing it.

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* Hmſtadt, Cre An-
als 1786.

† Cl, ou de b, 1785.

‡ ibl.

* Stahl's 300 Experiments.

expoſed to it: increaſe the fire towards the end, ſo that the whole matter contained in the crucible ſhall be moderately but ſenſibly red. In this ſtate throw it into two pints of water, and boil it for half an hour. Decant off this water, and continue to pour on more till it come off inſipid. Add all theſe liquids together, and boil them down to two pints. Diſſolve two ounces of ſulphat of iron and eight ounces of alum in two pints of boiling water; mix this with the former liquor while both are hot. An efferveſcence takes place, and a powder is precipitated of a green colour mixed with blue. Separate this precipitate by filtration, and pour muriatic acid upon it till it becomes of a beautiful blue; then waſh it with water and dry it.

Different explanations were given of the nature of this precipitate by different chemiſts. All of them acknowledged that it contained iron, but to account for the colour was the difficult point. Brown and Geoffroy, and Neumann, diſcovered in ſucceſſion, that a great many other animal ſubſtances beſides blood communicated to alkalies the property of forming Pruſſian blue. Macquer undertook an examination of this ſubſtance, and publiſhed the reſult of his experiments in the Memoirs of the French Academy for 1752.

534
Its compoſition diſcovered by Macquer.

He obſerved, that when alkali is added to a ſolution of iron in any acid, the iron is precipitated of a yellow colour, and ſoluble in acids; but if iron be precipitated from an acid by an alkali prepared as above deſcribed, by calcination with blood (which has been called a *Pruſſian alkali*), it is of a green colour. Acids diſſolve only a part of this precipitate, and leave behind an inſoluble powder which is of an intenſe blue colour. The green precipitate therefore is compoſed of two different ſubſtances, one of which is Pruſſian blue; the other, as he aſcertained by experiment, is the brown or yellow oxyd of iron; and the green colour is owing to the mixture of the blue and yellow ſubſtances. When heat is applied to the inſoluble precipitate, its blue colour is deſtroyed, and it becomes exactly ſimilar to common oxyd of iron. It is compoſed therefore of iron and ſome other ſubſtance, which heat has the property of driving off. If this inſoluble precipitate be boiled with a very pure alkali, it loſes its blue colour alſo, and at the ſame time the alkali acquires the property of precipitating of a blue colour ſolutions of iron in acids, or it has become preciſely the ſame with the Pruſſian alkali. Pruſſian blue, therefore, is compoſed of iron and ſomething which a pure alkali can ſeparate from it, ſomething which has a greater affinity for alkali than for iron. By boiling a quantity of alkali with Pruſſian blue, it may be completely ſaturated with this ſomething, which we ſhall call *colouring matter*, and then it has loſt all its alkaline properties. No acid can ſeparate this colouring matter from iron after it is once united with it. When iron diſſolved in an acid is mixed with an alkali ſaturated with the colouring matter, a double decompoſition takes place, the acid unites with the alkali, and the colouring matter with the iron, and forms Pruſſian blue. The reaſon that, in the common method of preparing Pruſſian blue, a quantity of yellow oxyd is precipitated, is, that there is not a ſufficient quantity of colouring matter (for the alkali is never ſaturated with it) to ſaturate all the iron diſplaced by the alkali; a part of it therefore is mixed with Pruſſian blue. Muriatic acid diſſolves this oxyd, carries it off, and leaves the blue in a ſtate of purity. Such were the concluſions which Macquer drew from his experiments; experiments which not only diſcovered the compoſition of Pruſſian blue, but threw a ray of light on the nature of affinities, which has contributed much towards the advancement of that important branch of chemiſtry.

The nature of the colouring matter, however, was ſtill unknown. Macquer himſelf ſuppoſed, that it was pure phlogiſton; but the opinion was untenable. He had ſhewn that it poſſeſſed the property of forming neutral ſalts, and therefore Bergman and Morveau ſuſpected that it was an acid.

Scheele undertook the taſk of examining its nature, and publiſhed the reſult of his experiments in the Stockholm Tranſactions for 1782.

He obſerved, that the Pruſſian alkali, after being expoſed for ſome time to the air, loſt the property of forming Pruſſian blue; the colouring matter muſt therefore have left it.

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Deco ſed b Sche

He put a ſmall quantity of it into a large glaſs globe, corked it up, and kept it ſome time; but no change was produced either in the air or the Pruſſian alkali. Something muſt therefore diſplace the colouring matter when the alkali is expoſed to the open air, which is not preſent in a glaſs veſſel. Was it carbonic acid gas? To aſcertain this, he put a quantity of Pruſſian alkali into a glaſs globe filled with that gas, and in 24 hours the alkali was incapable of producing Pruſſian blue. It is therefore carbonic acid gas which diſplaces the colouring matter. He repeated this experiment with this difference, that he hung in the globe a bit of paper which had been previouſly dipped into a ſolution of ſulphat of iron, and on which he had let fall two drops of an alkaline lixivium, in order to precipitate the iron. This paper was taken out in two hours, and became covered with a fine blue on adding a little muriatic acid. Carbonic acid, then, has the property of ſeparating the colouring matter from alkali without decompoſing it.

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Thec ing n ſepar

He found alſo that other acids produced the ſame effect. The colouring matter then may be obtained perhaps in a ſeparate ſtate. He accordingly made a number of attempts to procure it, and at laſt diſcovered the following proceſs: He boiled together for ſome minutes two ounces of Pruſſian blue in powder, one ounce of the red oxyd of mercury, and ſix ounces of water; then paſſed the whole through a filter, and waſhed the reſiduum with two ounces of boiling water. The oxyd of mercury has a greater affinity for the colouring matter than the oxyd of iron; it therefore unites with it, and forms with it a ſalt ſoluble in water. The iron remains behind upon the filter, and the liquid is a ſolution of the colouring matter combined with mercury. He poured this ſolution upon half an ounce of pure iron-filings, and added at the ſame time three grains of ſulphuric acid. The iron ſeparates the oxygen from the mercury, in order to combine with the ſulphuric acid; the mercury is precipitated in its metallic ſtate, and leaves behind it a quantity of ſulphat of iron and of colouring matter diſſolved in water, but not combined, as the colouring matter is unable to ſeparate the iron from the acid*.

He then diſtilled in a gentle heat; the colouring matter came over by the time that one-fourth of the liquor had paſſed into the receiver. It was mixed, however, with a ſmall quantity of ſulphuric acid; from which he ſeparated it by diſtilling a ſecond time over a quantity of carbonat of lime. The ſulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, becauſe carbonic acid has a ſtronger affinity for lime than it has. Thus he obtained the colouring matter in a ſtate of purity.

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* Ber llet, Ann. Chimi. 30.

37 Its compone parts. It remained now to diſcover its component parts. He formed a very pure Pruſſian blue, which he diſtilled, and increaſed the fire till the veſſel became red. The ſmall quantity of water which he had put into the receiver contained a portion of the blue colouring matter and of ammonia; and the air of the receiver conſiſted of azot, carbonic acid gas, and the colouring matter. He concluded from this experiment, that the colouring matter was compoſed of ammonia and carbon. He mixed together equal quantities of pounded charcoal and potaſs, put the mixture into a crucible, and kept it red hot for a quarter of an hour: he then added a quantity of ſal ammoniac in ſmall pieces, which he puſhed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceaſed to give out vapours of ammonia, and then threw it into a quantity of water. The ſolution poſſeſſed all the properties of the Pruſſian alkali. Thus Mr Scheele ſucceeded in forming the colouring matter; and it was conſidered as proved that it was compoſed of ammonia and carbon.

But after the publication of Scheele's experiments, it was diſcovered that ammonia itſelf is compoſed of azot and hydrogen. It became therefore a queſtion, whether ammonia entered into the compoſition of this ſubſtance, or merely its ingredients? whether it was compoſed of ammonia and carbon, or of azot, hydrogen, and carbon combined in a different manner? This point has been decided by the following experiments. Mr Clouet made a quantity of ammoniacal gas paſs through a red hot porcelain tube filled with charcoal, and by this proceſs formed a quantity of the colouring matter.* Here the temperature was ſo high, that the ammonia muſt have been decompoſed; and the colouring matter cannot be formed by combining ammonia and charcoal except at a temperature equally high. There is reaſon therefore to ſuppoſe that the ammonia is decompoſed. When oxy-muriatic acid is mixed with the colouring matter, it communicates to it a quantity of oxygen, and cauſes it in conſequence to aſſume very different properties. When a fixed alkali or lime is added to it in this ſtate, it is immediately decompoſed, and converted into ammonia and carbonic acid gas. The colouring matter in this ſtate contains all the ingredients neceſſary to form theſe two ſubſtances, namely, azot, hydrogen, carbon, oxygen; but in order to induce the ingredients to form theſe two compounds, the aſſiſtance of an alkali or lime to combine with the carbonic acid is neceſſary; juſt as ſulphur combines more eaſily with oxygen when united with an alkali or with iron than when ſeparate.*

The colouring matter, then, which we ſhall henceforth call the *Pruſſic acid*, is compoſed of azot, hydrogen, and carbon; but the proportions of theſe ingredients have not yet been determined. It is conſidered as an acid, though the preſence of oxygen has not been proved, becauſe it has the property of forming neutral ſalts with the ſame baſes as other acids.

538 Properties of Pruſſic acid. The Pruſſic acid is exceedingly volatile, and evidently capable of exiſting in a gaſeous ſtate. It has a peculiar odour, not diſagreeable, and which has been compared to the flowers of the peach. It has a ſweetiſh and ſomewhat hot taſte, and excites cough †.

It has no affinity for alumina nor for alcohol ‡.

This ſubſtance differs exceedingly in its action from all other acids.

539 Its action on other bodies. It is capable of combining, like them, with earths, alkalies, and metallic oxyds, and of forming compounds which have been denominated *Pruſſiats*. But it enters much more readily into triple compounds with alkalies or earths, and metallic oxyds, than into combinations with earths or alkalies ſeparately; and though its affinity appears to be greater for alkalies and earths than for metallic oxyds, yet when in a free or gaſeous ſtate it does not enter into combinations with earths or alkalies without difficulty, and it is ſeparated from them much more eaſily than from metallic oxyds. Mere expoſure to the light of the ſun, or to a heat of 110°, is ſufficient for that purpoſe.

540 Its affinities. Its affinities are ſuppoſed to be as follows;

Potaſs,
Soda,
Ammonia,
Lime,
Barytes,
Magneſia,
Oxyd of zinc,
——— iron,
——— manganeſe,
——— cobalt,
——— nickel,
——— lead,
——— tin,
——— copper,
——— biſmuth,
——— antimony,
——— arſenic,
——— ſilver,
——— mercury,
——— gold,
——— platinum (Y).

Sect. XXIX. *Of Formic Acid.*

541 Diſcovery of formic acid. In the 15th century ſeveral botaniſts obſerved with aſtoniſhment, that the flower of ſuccory, when thrown into an ant-hill, became as red as blood: But it was Mr S. Fiſher who firſt diſcovered that ants poſſeſſed a peculiar acid, which he obtained by diſtilling theſe animals. His experiments were publiſhed in the Philoſophical Tranſactions for 1670. Though Hoffman afterwards repeated his proceſs, little was known concerning the nature of this acid till Margraf undertook its examination,

* nn. de C n. xi.

* ertbollet, n. de im. i.

† *Scheele.*

‡ *Morveau.*

(Y) We ſuſpect that this is not the real order of the affinities of this acid; the metallic oxyds ought probably to be placed before the alkalies and earths, and the metallic Pruſſiats ought to occupy the place which is at preſent filled by the metallic oxyds. The reaſons for this conjecture will appear afterwards. See Part III. chap. ii. ſect. 23. of this article.

Formic Acid.

mination, and publiſhed his experiments in the Berlin Memoirs for 1749.

The ſpecies of ants from which the formic acid is obtained is the *formica rufa*, which reſide moſt commonly in woods, or at leaſt in elevated and dry places. They have been found to contain the greateſt quantity of acid in the months of June and July. If at that ſeaſon one of theſe animals be preſſed upon paper tinged with turnſole, it changes the colour of it to a moſt lively red; they even ſometimes ſtain it merely by crawling over it.

542
Method of obtaining it.

There are two methods of obtaining the formic acid, diſtillation and lixiviation.

When the firſt method is to be employed, the ants are to be waſhed clean, dried with a gentle heat, put into a retort, and diſtilled with a moderate heat, gradually increaſed till all the acid has come over. It is mixed with an empyreumatic oil, from which it is ſeparated by paſſing it through a ſtrainer previouſly moiſtened with water. By this proceſs Meſſrs Ardviſſon and Oehrn obtained from a pound of ants 7½ ounces of acid, the ſpecific gravity of which, at the temperature of 60°, was 1,0075.* Morveau obtained from 49 ounces of ants 23 ounces of pretty ſtrong acid †. Margraf added a quantity of water, but it is evident that this ſerves merely to weaken the acid.

When the other method is preferred, the ants are to be waſhed in cold water, put upon a clean linen cloth, and boiling water poured on them repeatedly till it can extract no more acid. The linen is then to be ſqueezed, and the ſeveral liquors mixed and filtrated. This method was firſt uſed by Ardviſſon and Oehrn: they obtained from a pound of ants an acid liquor which had more ſpecific gravity than common vinegar. It is to be purified from the oil which adheres to it by repeated diſtillations. After four diſtillations the empyreumatic oil ſtill manifeſts its preſence by its ſmell, but this ſmell vaniſhes if the acid be expoſed for ſome time to the air; a quantity of eſſential oil, however, ſtill remains, which cannot be ſeparated. The ſpecific gravity of the acid thus rectified is 1,0011 ‡.

Hermſtadt employed a third method. He expreſſed the juice of dry ants, and by this means obtained from 2 lbs. of theſe animals 21 oz. 2 dr. of juice, which on diſtillation yielded a clear pure acid, equal in ſtrength to very concentrated vinegar.*

543
Its properties.

This acid ſeems to be capable of aſſuming a gaſeous form; at leaſt Hermſtadt obſerved, that when he put ſome of it into a bottle with a glaſs ſtopper, the ſtopper was frequently raiſed by an elaſtic fluid making its eſcape, and that after ſome days it had loſt its ſmell †. When this acid is boiled with nitric acid, a gas is extricated, which renders lime water turbid, and has a very pungent odour †.

This acid has a ſtrong but not unpleaſant ſmell, a cauſtic taſte, and when much diluted a pleaſant acidity. When moſt concentrated, its ſpecific gravity is 1,0453 ‡.

One part of this acid, mixed with 75 parts of water, gives a faint red to ſyrup of violets; mixed with 430 parts of water, it reddens paper coloured with turnſole; mixed with 1300 parts of water, it produces no effect on the infuſion of turnſole ‡. It mixes readily with alcohol.

It unites readily with the other acids. When boiled with ſulphuric acid, it becomes black. White acrid vapours riſe when the mixture becomes hot; and when it boils, a gas riſes which unites with difficulty to water and lime-water; the formic acid is again obtained, but its quantity is diminiſhed §.

Nitric acid decompoſes it altogether, and is itſelf converted into nitrous acid. Muriatic acid does not alter it. Oxy-muriatic acts like nitric acid.*

5
Its co poun affini

Its compounds are called *formiats*.

Its affinities are the ſame with thoſe given above for the Pruſſic acid.

Sect. XXX. *Of Sebacic Acid.*

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Diſc of ſe aci

Chemists had long ſuſpected that an acid could be obtained from tallow, on account of the acrid nature of the fumes which it emitted at a high temperature; but it was M. Grutzmacher who firſt demonſtrated this acid in a diſſertation *De Oſſium Medulla*, publiſhed in 1748 ‡. M. Rhodes mentioned it in 1753, and Segner publiſhed a diſſertation on it in 1754, and Crell examined its properties very fully in two diſſertations publiſhed in the Phil. Tranſ. for 1780 and 1782. It was called at firſt *acid of fat*, and afterwards *ſebacic acid*.

It may be procured by heating together a mixture of ſuet and lime. Sebat of lime is formed, which may be purified by ſolution in water. It is then to be put into a retort, and ſulphuric acid poured on it. Sebacic acid paſſes over on the application of heat.

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Its p ties,

Sebacic acid has an acid, ſharp, bitteriſh taſte, and a very pungent ſmell. It reddens tincture of litmus.

Heat cauſes it to aſſume a yellow colour.

It oxydates ſilver, mercury, copper, iron, lead, tin, zinc, antimony, mangeneſe.

It does not act upon biſmuth, cobalt, nickel. When mixed with nitric acid it diſſolves gold.

Its compounds are called *ſebats*.

5
Com poun and nitie

Its affinities, according to Morveau, are as follows:

Barytes,
Potaſs,
Soda,
Lime,
Magneſia,
Ammonia,
Alumina,
Jargonia †,
Oxyd of zinc,
——— manganeſe,
——— iron,
——— lead,
——— tin,
——— cobalt,
——— copper,
——— nickel,
——— arſenic,
——— biſmuth,
——— mercury,
——— antimony,
——— ſilver,

Sect. XXX. *Of Bombyc Acid.*

5
Diſc of b acid.

Mr Boissier de Sauvages obſerved, that the juice of the ſilkworm, in the diſeaſe called in France *muſcadine*, was acid; and Chauſſier remarked, that the ſilkworm, after being converted into a butterfly, gives out

* *Diſſert. on the Acid of Ants*, 1777, in *Baldinger's New Magazine for Arts.*

† *Encycl. Method.* i. 61.

‡ *Ardviſſon and Oehrn, ibid.*

* *Crell's Annals*, 1784.

† *Ibid.*

† *Ardviſſon, ibid.*

‡ *Ibid.*

‡ *Morveau*, p. 62.

§ *Ibi*

* *Ibi*

† *Va Ann. Chim* 208

make an integrant of any ſubſtance. Water, for inſtance, conſiſts of oxygen and hydrogen; but when we ſpeak of a particle of water, we do not mean the oxygen or the hydrogen ſeparately, but the ſmalleſt poſſible quantity of theſe combined in ſuch a manner as to form water. It is the *integrant particles* of bodies which are united by affinity. Thus ſulphuric acid is compoſed of ſulphur and oxygen combined together; and ammonia, of hydrogen and azot combined in the ſame manner. Now when ſulphuric acid and ammonia combine, it is not their elements, ſulphur, oxygen, azot, and hydrogen, which unite together, particle with particle, but the particles of the acid and the alkali as integrants. This is evident; becauſe if theſe ſubſtances be ſeparated from each other by means of a ſtronger affinity, they are found preciſely in the ſame ſtate as before they entered into combination.—When the ſubſtances which combine are *ſimple*, the ultimate and integrant particles are the ſame: But we are not certain that any of the bodies with which we are acquainted is ſimple, in the ſtrict and proper ſenſe of the word.

564 Opinions of the older chemiſts about affinity.

2. What is this *affinity* which unites bodies together? The older chemiſts thought that all ſolvents, or ſubſtances capable of diſſolving others, were compoſed of particles which had the form of wedges or hooks; that ſolution conſiſted in the inſinuation of theſe wedges or hooks between the particles of the bodies to be diſſolved; and that chemical combination was merely the linking of the different particles together by means of holes in one ſet of particles, into which the hooks or the wedges of the other ſet were thruſt. Such explanations, abſurd as they may appear, were faſhionable among chemical philoſophers till the days of Sir Iſaac Newton, who firſt aſcribed the chemical union of bodies to an *attraction* between the particles themſelves. This explanation, after a violent ſtruggle on the part of the chemiſts, has been at laſt unanimouſly adopted.

565 It is an attraction between the particles of bodies.

Affinity, then, is an *attraction* between the particles of different bodies, by which they are *drawn* towards one another, and kept united. This we take for granted, and conſider as a *fact*, without pretending to explain *how* they come to be poſſeſſed of this power, or *how* they exert it; both of which are evidently beyond the reach of the human underſtanding.

566 Whether the ſame with gravitation.

But though we cannot diſcover the manner in which affinity acts, we can ſee, at leaſt, that it follows certain laws, and that they are invariable; for ſimilar phenomena always occur when the circumſtances are the ſame. Now what are the laws which affinity follows? There is a ſpecies of attraction which matter poſſeſſes, called *gravitation*, the laws of which were inveſtigated by Sir Iſaac Newton. Is affinity the *ſame* with gravitation, or does it follow different laws?

Upon a ſlight view of theſe two attractions, their phenomena appear very differnt. Gravitation acts at very great diſtances; affinity not until the bodies are mixed together: Gravitation acts on the whole maſs; affinity only on the particles: Bodies gravitate to one another directly as their maſſes, and inverſely as the ſquares of their diſtances. But how can affinity follow theſe laws, when it does not act till the bodies are apparently in contact? or ſuppoſing that it does act, how can they account for the phenomena of affinity? If barytes be preſented to a compound of ſulphuric acid and potaſs, the acid immediately leaves the alkali and combines with the earth: But had gravitation been the only power acting, ought not the barytes to have united with the ſulphat of potaſs without producing any decompoſition?

Theſe ſtriking differences have convinced many philoſophers, as they ſeem to have done Newton himſelf, that gravitation and affinity are different ſpecies of attraction. Let us not, however, embrace this concluſion vaguely, or without affixing a preciſe meaning to our words.

567 No poſi proof it is rent.

Gravitation and chemical affinity are ſaid to be different ſpecies of attraction. But what is attraction? It is merely a general *fact*, or that tendency which is *obſerved* among all the portions of matter towards each other, but which exhibits very different appearances under different circumſtances. The tendency of matter towards matter at *ſenſible* diſtances is called *gravitation*, and its laws have been completely inveſtigated; but neither that tendency, nor theſe laws, have been, or can be, ſhewn to be *eſſential* to the exiſtence of matter. Chemical affinity is the tendency of particles towards each other at *inſenſible* diſtances, or when theſe particles are mixed together; and this tendency appears to be regulated by laws different from thoſe of gravitation. Like gravitation, it is merely an *obſerved fact*; and however different theſe facts may appear to be, they are probably both brought about by the ſame forces. It is indeed true, that gravitation is directly as the maſſes of matter, and inverſely as the ſquares of the diſtances of theſe maſſes; while the attraction, which is called *chemical affinity*, ſeems to obſerve very different rules. But we have ſhewn elſewhere (ſee Optics, n° 62—68, *Encycl.*; and Boscovich in this *Suppl.*), that the ſame forces repel at one diſtance and attract at another; and that they may produce all the various phenomena of chemical affinity.

The difficulties to be accounted for in chemical affinities are their intenſity, their different degrees of ſtrength, and their being elective, or, which is the ſame thing, the capacity which one body has of diſplacing another.

How come affinities, it may be aſked, to differ in intenſity? Perhaps we might with propriety refer this queriſt to the ſtudy of Boſcovich's curve; but as our modern chemiſts are not generally verſant in ſuch ſtudies, we beg leave to obſerve, in this place, that we have no proof whatever of abſolute contact between bodies. On the contrary, it is highly probable, we had almoſt ſaid demonſtrable, that particles are in every inſtance at ſome diſtance from one another. For, on the ſuppoſition that two bodies were in actual contact, their attraction for each other would not only be as great as poſſible, but as great as the attraction of any other body for either of them *could poſſibly* be: Conſequently, it neceſſarily follows, that, ſince bodies chemically combined *can* be ſeparated, they are not in actual contact (A); but if they are not in contact, their diſtance from one another

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(A) Perhaps the following demonſtration, which we borrow from the ingenious Mr Brougham, will render this more evident. In fig. 7. let the body A have for P an attraction which at the diſtance of AP is proportional

Plate XVIII.

another *may* vary in different caſes, and the force of affinity will vary with the diſtance. Here then is a reaſon why the affinity of different bodies varies in ſtrength. Sulphuric acid, for inſtance, has a ſtronger affinity for barytes than for lime; becauſe when the combinations are formed, the diſtance between the acid and barytes is not ſo great as that between the acid and lime.

But why do the diſtances differ? If affinity be the ſame with gravitation it muſt tend to bring the particles nearer one another: and what then prevents the lime from approaching as near the acid as the barytes does? We reply, *the figure of its particles.* This anſwer was firſt given to the queſtion by Buffon, and it is fully adequate to ſolve the difficulty. The particles of bodies, indeed, are a great deal too minute for us to diſcover their figure by actual inſpection; but the phenomena of cryſtallization ſhow us that this difference actually exiſts.

The cryſtals of every body aſſume a peculiar figure. Now as theſe cryſtals are all formed in the ſame manner, and by the ſame law, it is impoſſible to conceive any other reaſon for their variety, but the difference in the form of the particles which compoſe them.

But why does one body diſplace another? When a particle of barytes is brought within a certain diſtance of a particle of ſulphuric acid and lime combined together, affinity acts, and draws them nearer to one another; and the barytes, from its figure, approaches nearer the acid than the lime could, and forms with it a compound, the figure of which is ſuch, relatively to that of the lime, that they cannot approach within a ſmall enough diſtance of each other to counteract the attraction of the earth. Accordingly, no compound is formed; for all that is meant by two particles having formed a compound is, that their attraction for each other is greater than the attraction of the ſurrounding bodies for either.

68 Coſe-quently it ought to be conſidered as the *ſame*.

Having thus ſeen that none of the phenomena of *affinity* are inconſiſtent with their reſulting from the forces which bring about the phenomena of gravitation, we have a right to conclude that it is at leaſt highly probable, that all the motions of the corporeal world are produced by the ſame power which, though not eſſential to matter, was impreſſed upon every atom of it by the Great Creator when he formed this univerſe; and that as the effects of this power are modified according to the ſituation of the bodies on which it acts, they are known by the different names of *gravity*, *adheſion*, *coheſion*, and *affinity*.

Gravity is the attraction between bodies ſo diſtant, that the maſſes alone influence the reſult, and that the power may be conſidered as placed in the centre of the attracting bodies.

Adhesion ſuppoſes a diſtance too ſmall for our ſenſes. It has been demonſtrated to be proportional to the number of touching points, which depends upon the figure of the particles that form the bodies.

Cohesion takes place only between particles of the ſame nature. Theſe, inſtead of touching only in one ſuperficies, as in adheſion, touch in every point where their figure will allow contact: conſequently the force of coheſion alſo muſt depend upon the figure of the particles.

Affinity unites bodies of a different nature, not merely by one ſuperficies, as *adheſion* does, but particle to particle, like *coheſion*; and the moſt perfect contact is formed that the figure of the particles will admit. Therefore, in this caſe alſo, the intenſity depends upon the figure of the particles.

569 Saturation explained.

3. If we make the attempt, we ſhall find that water will not diſſolve any quantity of common ſalt that we pleaſe. Water which refuſes to take up any more is ſaid to be *ſaturated* with ſalt. Neither can we combine *any* quantity of potaſs with a given portion of ſulphuric acid: we may add as much of it as we pleaſe, indeed; but if we evaporate the liquid, in order to obtain the ſalt in cryſtals, we ſhall find that only *part* of the potaſs has united with the acid, and that the reſt has cryſtallized ſeparately. From theſe examples, it muſt appear evident, that bodies combine with one another by affinity, only in certain proportions; or, which is the ſame thing, that a determined number of particles of each of the ingredients goes to the formation of an integrant particle of the compound, and that into this integrant *no additional particles* of either ingredient *can* be admitted. Let us ſuppoſe, for inſtance, that the particles of ſulphuric acid are tetrahedrons, and that the particles of potaſs are of ſuch a form, that one of them can attach itſelf to each of the ſides of the acid particle: In that caſe, an integrant particle of ſulphat of potaſs would be compoſed of five particles, one of acid and four of alkali; for it is evident, that juſt four particles of potaſs would combine with every particle of acid, and that the acid would then be ſaturated, or, which is the ſame thing, would be incapable of receiving any more alkaline particles into combination with it. Let us ſuppoſe, now, that there is juſt as much potaſs as ſaturates the acid; if more acid be poured in, it cannot enter into combination with the potaſs, becauſe all the potaſs is already combined with acid.

Thus it appears evident, from the nature of affinity, that the ingredients in every combination muſt mutually *ſaturate* each other, and that no more of either can be

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tional to PM; then let P move towards A, ſo as to come to the ſituation P', and let the attraction here be $P'M'$; as it is continual during the motion of P to P', $M'M'$ is a curve line. Now in the caſe of the attraction of bodies for one another, PM is leſs than $P'M'$; and conſequently MM' does not ever return into itſelf, and therefore it muſt go *ad infinitum*, having its arc between AB and AC, to which it approaches as aſymptotes, the abſciſſa always repreſenting the diſtance, and the ordinate the attraction at that diſtance. Let P' now continue its motion to P'' and M' will move M''; and if P'' meets A, or the bodies come into perfect contact, $P''M'$ will be infinite; ſo that the attraction being changed into coheſion will be infinite, and the bodies inſeparable, contrary to univerſal experience; ſo that P can never come nearer to A than a given diſtance. *Nicholſon's Journal*, I. 555.

100 parts of potaſs require	78,5	Sulphuric acid,
	64	Nitric;
	51,5	Muriatic,
	42	Carbonic,
100 parts of ſoda - -	177	Sulphuric,
	135,5	Nitric,
	125	Muriatic,
	80	Carbonic.

This propoſition, which has been admirably illuſtrated by Morveau†, evidently reſolves itſelf into the two following:

1. A *baſe* requires the *more* of an acid for ſaturation *the ſtronger* its affinity for that acid is.

2. An *acid* requires *the more* of any baſe for ſaturation *the greater affinity* it has for that baſe.

In order to judge of the truth of the firſt of theſe propoſitions, let us examine the following table, drawn up from the experiments of Bergman, Wenzel, and Kirwan.

100 parts of	Bergman.			Wenzel.			Kirwan.		
	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.
Barytes	15,4		30,8						
Potaſs	78,6	64	51,5	82,4	107,7	54	81,8	87,1	78,2
Soda	175	135,5	125	125,8	166,6	83	129,4	136,1	114,2
Lime	143,7	134,4	70,45	147,74	195,6	103,6	141	180	86
Magneſia	173,67	159,25	82,92	181,8	257,15	122,27	170,5	255	104,275
Ammonia				142,42	201,22	96,25	187,5	233	116
Alumina	211,11		220,2	77,7	68,7	38,6			

It is evident at firſt ſight, that Bergman's experiments correſpond exactly with the propoſition. To ſaturate, according to him, 100 parts of potaſs, requires 78,6 of ſulphuric acid, 64 of nitric, and 51,5 of muriatic acid. There is only one deviation from the propoſition in the whole table, and this regards barytes, which, according to him, is ſaturated with 15,4 of ſulphuric and 30,8 of muriatic acid. But Mr Morveau has ſhewn, by ſeveral accurate experiments, that barytes requires much more ſulphuric acid for ſaturation than Bergman ſuppoſed§. And Klaproth has ſhewn, that 100 parts of barytes require 49,2 of ſtrong ſulphuric acid for ſaturation*. And Dr Withering's calculation† agrees almoſt exactly with this; nor does that of Fourcroy differ much from it‡. Inſtead of 15,4 of ſulphuric acid, therefore, which, according to Bergman, are neceſſary to ſaturate 100 of barytes, it ſhould be 42,8.

The firſt and laſt columns of Wenzel and Kirwan's experiments agree equally well with the propoſition, but the ſecond deviates from it completely. Wenzel probably might have been miſled by the manner of performing his experiments; but the ſame objection does not ſeem to lie againſt thoſe of Kirwan.

It can ſcarcely be doubted, however, to whatever cauſe the error is to be imputed, that the numbers in the ſecond column of Mr Kirwan's table are too large. The following experiment of Morveau is ſufficient to ſhew this.

According to Mr Kirwan's experiments, the proportions of acid and alkali in the four following ſalts are as under:

Sulphat of potaſs	Acid	100
	Potaſs	108,7
Sulphat of lime	Acid	100
	Lime	80,6
Nitrat of potaſs	Acid	100
	Potaſs	83,33
Nitrat of lime	Acid	100
	Lime	34,4

Now when ſulphat of potaſs and nitrat of lime are mixed together, a double decompoſition takes place, and ſulphat of lime and nitrat of potaſs are formed. Let theſe two ſalts be mixed together; let the quantity of ſulphat of potaſs be ſuch, that the acid contained in it amounts to 100; and let a more than ſufficient quantity of nitrat of lime be added, to ſaturate the ſulphuric acid with lime. It is evident that for that purpoſe 80,6 of lime muſt be preſent; and the quantity of nitric acid combined with theſe 80,6 muſt be 234,4. This quantity would require for ſaturation 195,32 of potaſs, but there are only 108,7 in the mixture; conſequently there ought to exiſt in the mixture, after the mutual decompoſition of the ſalts, 64,87 of nitric acid in a ſtate of liberty. Such would be the reſult, provided Mr Kirwan's numbers were accurate; but the fact is, that no ſuch exceſs of acid exiſts in the mixture*; and conſequently the quantity of nitric acid contained in nitrat of lime is ſtated too high by Mr Kirwan. Although therefore Mr Kirwan's tables do not coincide with the propoſition which we are conſidering, this is not to be conſidered as a proof of its falſehood; as there is reaſon, from the experiment above deſcribed, to ſuſpect ſome error in the data from which Mr Kirwan calculated the ſtrength of the acids.

The truth of the ſecond propoſition may be judged of by the following tables:

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† *Encycl. Method. Chim.* i. 597.

§ *cycl. Mod. Cl.* i. 591.

* *im. A.* ii. 17.

† *bil. T.* 1784.

‡ *n. de Ch.* iv. 65.

* *Ann. de Chim.* xxv. 295.

TABLE II. *Ratios of the Affinity of three Acids for ſix Baſes.*

	Sulp. acid	Nitr. acid	Mur. acid
Barytes	100,00	90,42	74,54
Potaſs	100,00	79,01	65,30
Soda	100,00	80,03	62,35
Lime	100,00	92,24	60,05
Magneſia	100,00	90,34	59,68
Ammonia	100,00	90,02	62,77

TABLE III. *Affinity between three Acids and ſix Baſes in Abſolute Numbers.*

	Sulp. acid	Nitr. acid	Mur. acid
Barytes	10000	9042	7454
Potaſs	5285	4537	3794
Soda	3373	2969	2419
Lime	2927	2653	2143
Magneſia	2434	2193	1786
Ammonia	2112	1763	1515

On the ſuppoſition that the two propoſitions mentioned above were ſtrictly true, and that the numbers which we fixed upon were preciſely the quantities of acid and baſe neceſſary to ſaturate each other reciprocally, this laſt table would repreſent accurately in numbers the ſtrength of the affinities of the three acids for each of the ſix baſes reſpectively.

We muſt acknowledge, however, that the truth of theſe propoſitions has not hitherto by any means been ſufficiently proved; but a great number of facts concur to render them exceedingly probable, and highly worthy of the attention of chemical philoſophers. And we hope that the method propoſed by Morveau, and which had been previouſly practiſed by Richter, of verifying theoretical calculations of the compoſition of the ſalts, by mixing together two ſalts which mutually decompoſe each other, and aſcertaining whether the reſult correſponds with calculation, will be followed out, and that it will be the means of enſuring more accuracy than it has hitherto been poſſible to obtain.

No one will ſuſpect that any thing which has here been ſaid is meant as a reflection on the ingenious chemiſts who have attempted to ſolve this moſt difficult of all chemical problems, the proportion of the ingredients which enter into the compoſition of the ſalts. Mr Kirwan, in particular, is entitled to the greateſt praiſe for the perſevering induſtry with which he has proſecuted the ſubject, for the candour which he has diſplayed, and for the new route which he has opened to the chemical philoſopher. Though this problem has not hitherto been ſolved, and though the difficulties which ſurround it are almoſt inſurmountable, we may hope much from the general ſenſe which is at preſent entertained of its importance, and from the zeal and abilities of thoſe philoſophers who have particularly turned their attention to it.

In the mean time, the following table of the ſtrength of affinities by Morveau, though the numbers be arbitrary, will be found of very great uſe†.

† *Encycl. Method. Chim.* i. 773.

579 Morveau's table of affinity.

	Sulph. acid.	Nitric acid.	Muriat acid.	Acet. acid.	Carbo. acid.
Barytes	66	62	36	28	14
Potaſs	62	58	32	26	9
Soda	58	50	31	25	8
Lime	54	44	24	19	12
Ammonia	46	38	21	20	4
Magneſia	50	40	22	17	6
Alumina	40	36	18	15	2(D)

580 Three claſſes of affinity,

5. Although every chemical combination is produced by the ſame general law, yet as their phenomena vary ſomewhat according to circumſtances, affinities have, for the ſake of greater perſpicuity, been divided into claſſes. Theſe claſſes may be reduced to *three*—*ſimple*, *compound*, and *diſpoſing* affinities.

581 Viz. ſimple affinity,

The *firſt claſs*, comprehends all thoſe caſes in which only *two bodies combine* together; as, for inſtance, ſulphuric acid and potaſs, oxygen and carbon. The affinities which belong to this claſs are known by the name of *ſimple* or *ſingle affinities*. Although one of the ſubſtances to be combined happens to be already united with another body, the combination is ſtill reckoned a caſe of ſingle affinity. Thus ſuppoſe the ſulphuric acid previouſly combined with magneſia, and forming with it the ſalt called *ſulphat of magneſia*, as ſoon as potaſs is preſented, the acid leaves the earth (which is precipitated), and unites with the alkali. Even when three bodies combine, it often happens that the union is produced merely by ſingle affinity. Thus, when ſome potaſs is dropped into tartarous acid, part of the acid unites with the alkali, and forms tartrite of potaſs; after this the remainder of the acid combines with the tartrite juſt formed, and compoſes a new ſalt known by the name of *acidulous tartrite of potaſs*, or *tartar*. This is evidently nothing elſe than two inſtances of ſimple affinity immediately following each other.

582 Compound affinity,

When more than three bodies are mixed, decompoſitions and new combinations often take place, which could

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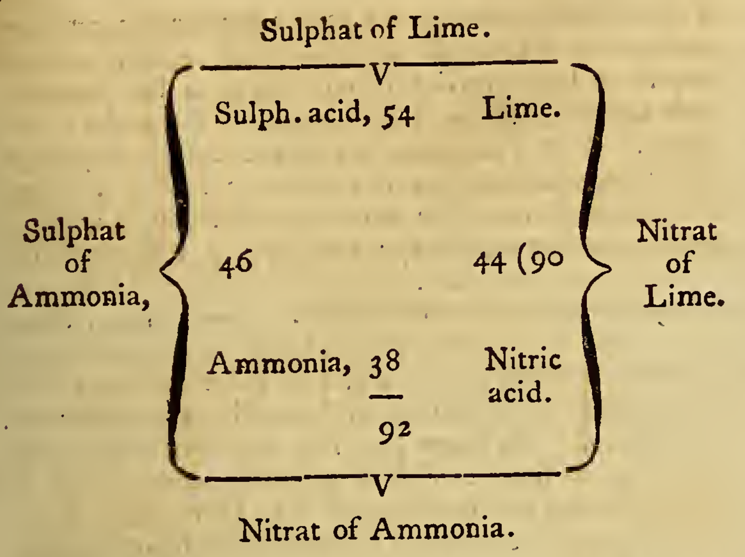
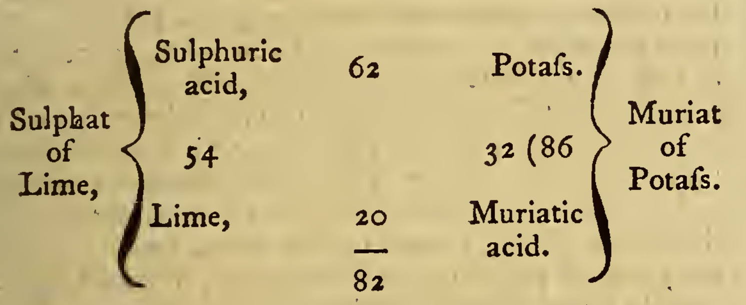
(D) This table, however, does not correſpond quite accurately to all the phenomena. For inſtance, according to it, ſulphat of barytes is not decompoſed by carbonat of ſoda, although the contrary takes place in fact.

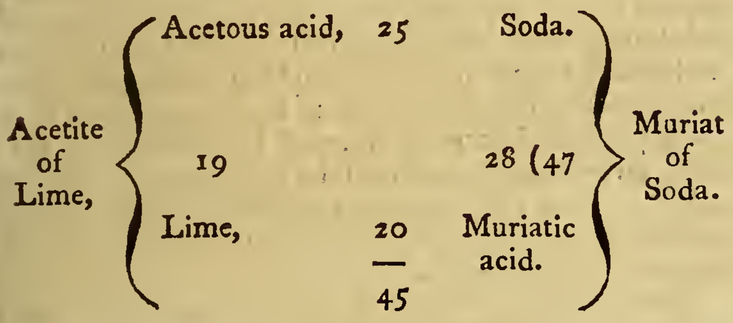


Suppoſing Morveau's numbers exact, it follows alſo, even prior to experiment, that no decompoſition takes place when ſulphat of lime and muriat of potaſs are mixed;



for the quieſcent affinities are 86 and the divellent only 82.

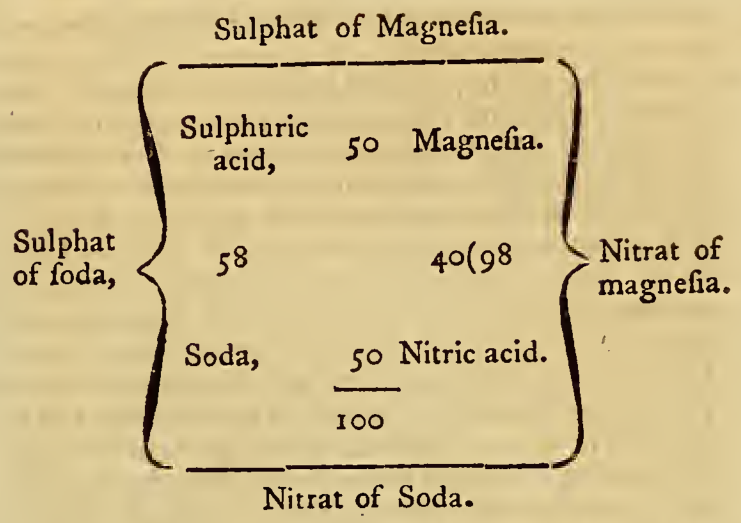
Nor when acetite of lime and muriat of ſoda are mixed;



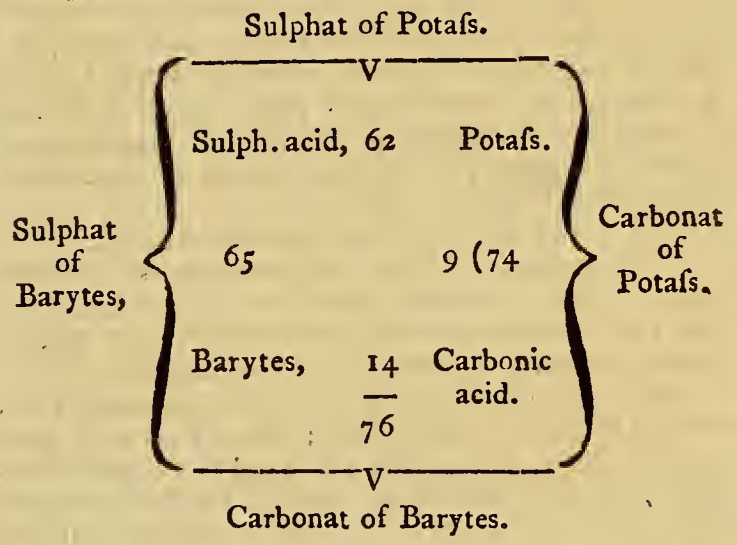
becauſe the quieſcent affinities are 47, and the divellent only 45. Theſe caſes where no decompoſition takes place, have been called by Morveau caſes of *inverſe* compound affinity.

Morveau has propoſed the following improvements in repreſenting theſe caſes of compound affinities‡:

When decompoſition does not take place, nothing is to be written above and below the ſquare, as in the two laſt examples. When a new compound remains diſſolved, a ſtraight line is to be placed between it and the ſquare, as in the following ſcheme.



When a new compound is precipitated, a line bent downwards in the middle is to be placed between it and the ſquare, as in the following ſcheme:



When a new compound is ſublimed, the line between it and the ſquare is to be pointed upwards in the middle, thus ⌐——^——¬.

When a new compound is partly diſſolved and partly precipitated, the line placed between it and the ſquare is to aſſume the following ſhape: ____⌐——¬.

When it is partly diſſolved and partly ſublimed, the following is the line to be uſed: ‾‾‾‾⌐——¬.

583 And diſpoſing affinity.

The third claſs of affinities has been called by Mr Morveau *diſpoſing affinities*, becauſe they *diſpoſe* ſubſtances to combine that would not otherwiſe have done it. Suppoſe, for inſtance, that ſulphur is preſented to oxygen gas, it does not manifeſt any affinity for it; but combine it previouſly with potaſs, and it unites with oxygen with avidity. Its previous union with potaſs, in this caſe, *diſpoſed* it to unite with oxygen. The cauſe of this curious affinity is not yet well underſtood. If we conſider what it was that prevented the ſulphur and oxygen from combining, we ſhall find, that it can only be its own attraction of coheſion, and the affinity between the oxygen and caloric which are combined. Whatever then diminiſhes this attraction of coheſion, or of *aggregation* as it has been called, muſt facilitate the union of

‡ ncycl. thod. Cn. i. 5.

Let now a quantity of caloric be added to the oxygen and hydrogen gas, it has the property of expanding them, and of courſe of diminiſhing their coheſion; while its affinity for them is ſo ſmall that it may be neglected. Let us ſuppoſe that it diminiſhes the coheſion of the oxygen 1, and of the hydrogen alſo 1, their coheſion will be now 3 and 1; and the quieſcent affinities being only 104, while the divellent are 105, decompoſition would of courſe take place, and a quantity of caloric would thus be ſet at liberty to produce the ſame effects upon the neighbouring particles.

Thus, then, caloric acts only by diminiſhing coheſion: And the reaſon that it is required ſo much in gaſeous ſubſtances, and in thoſe combinations into which oxygen enters, is the ſtrong affinity of oxygen and the other baſes of the gaſes for caloric; for, owing to the repulſion which exiſts between the particles of that ſubtile ſubſtance, an effect is produced by adding large doſes of it contrary to what happens in other caſes. The more of it is accumulated, the ſtronger is the repulſion between its particles; and therefore the more powerful is its tendency to fly off: and as this tendency is oppoſed by its affinity for the body and the coheſion of its particles, it muſt diminiſh both theſe attractions.

Though we have thus attempted to explain what has been always conſidered as one of the moſt difficult problems in chemiſtry, we are far from ſuppoſing that we have removed every difficulty. Much ſtill remains to be done before the action of light and caloric can be fully underſtood: and there may be other agents, of whoſe exiſtence we have not yet even conceived the idea.

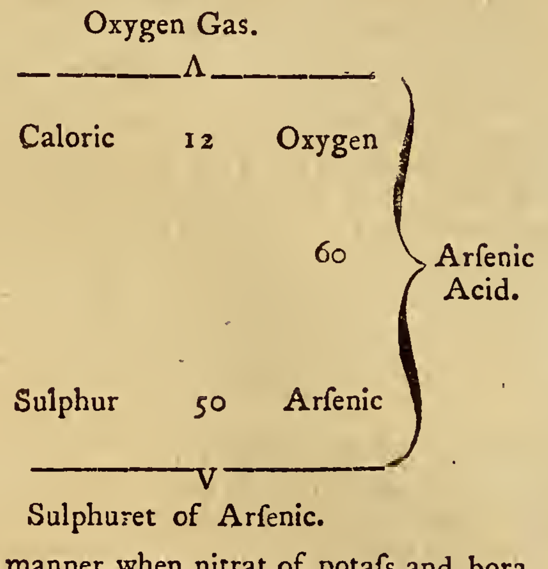
One difficulty ſtill remains to be examined. Heat not only produces the combination of ſome bodies, but alſo occaſions the decompoſition of others. How does it act in theſe caſes?

586 How heat decompoſes bodies.

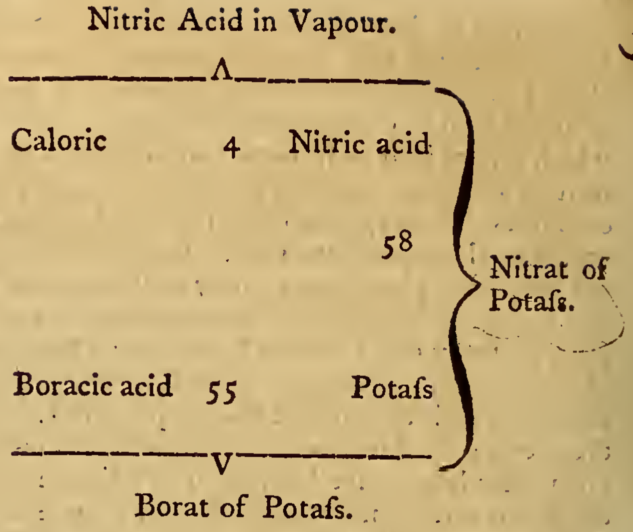
That many of theſe decompoſitions are produced by chemical affinity, will be evident from the following examples.

When ſulphur and arſenic acid are expoſed to heat, ſulphuret of arſenic is formed† evidently by a kind of compound affinity.

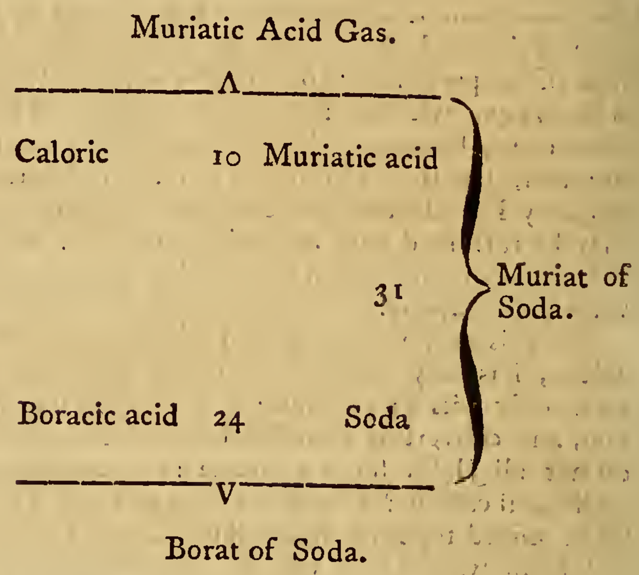
† Pelletier.



In the ſame manner when nitrat of potaſs and boracic acid are expoſed to heat, the nitric acid is volatilized, and borat of potaſs is left behind.



By the ſame compound affinity boracic acid and heat decompoſe muriat of ſoda.



In the ſame manner it would be eaſy to explain how all the decompoſitions by the *dry way*, as it is called, are produced.

But how comes caloric to decompoſe water after having produced the union of oxygen and hydrogen? The union, we have ſeen, was probably brought about by the play of oppoſite affinities; but in the ſeparation, caloric ſeems to act by its peculiar power, or the repulſion which exiſts between its particles. When caloric combines with an integrant particle of water, this repulſion muſt ſeparate the component parts ſomewhat from one another; conſequently it muſt weaken their affinity; for every increaſe of diſtance produces that effect. Now let us ſuppoſe that the affinity between oxygen and hydrogen is 105, and that the affinity between caloric and each of theſe bodies is 50: as ſoon as the particles of oxygen and hydrogen are ſo far ſeparated from each other that their affinity is leſs than 100, they will unite with caloric in preference, becauſe the ſum of their affinities for caloric is equal to 100; conſequently, whenever that takes place, water will be decompoſed. Hence we ſee the reaſon why more heat is always neceſſary to produce the decompoſition of bodies than what produced their union.

Caloric poſſeſſes another ſingular property, that of changing the compound affinities of bodies, even when it does not appear to enter as an ingredient. What we mean will appear evident from the following examples:

Muriat of ammonia, } decompoſe each other at the
Carbonat of magneſia,

ordinary temperature of the atmoſphere, and form muriat of magneſia and carbonat of ammonia: but, on the contrary,

Muriat of magneſia, and } decompoſe each other at
Carbonat of ammonia,

a high temperature; for inſtance, at 212°. The products are muriat of ammonia and carbonat of magneſia*.

Again, if muriat of ſoda and ſulphat of magneſia be mixed together at a low temperature, for inſtance, at zero, they decompoſe each other, and muriat of magneſia and ſulphat of ſoda are formed; but no decompoſition takes place at a temperature above 32°.—Muriat of ſoda, and ſulphat of alumina, exhibit preciſely the ſame phenomena†.

Laſtly, ſulphat of magneſia and carbonat of ammonia decompoſe each other at the ordinary temperature; but at 212° the carbonic acid flies off, and the remaining ſubſtances form a triple ſalt‡.

The laſt of theſe phenomena appears owing to the affinity between carbonic acid and caloric, and the two firſt to the affinity between muriat of ammonia and caloric, for that ſalt is volatilized.

It would not be ſo eaſy to explain the mutual decompoſition of muriat of ſoda and ſulphat of magneſia at a low temperature. It is probably connected with the alterations in the diſtance of the ingredients of chemical compounds, which are produced by the preſence and abſence of caloric.

587
Count
umford's
inion re-
cting af-
ity.

From the important part which caloric acts in chemical combinations, Count Rumford has been lately induced to ſuſpect that this ſubtile fluid is the *only agent* by which they are produced.

That caloric is a *neceſſary* agent in all chemical decompoſitions and new combinations, we very readily allow; becauſe we know no other cauſe except caloric to prevent the particles of bodies from actual contact; in which caſe decompoſition would be impoſſible: and if this be the ſenſe in which that ingenious philoſopher aſcribes chemical combinations to caloric, we very readily agree with him; but if he ſuppoſes that caloric is the *agent* by which the particles of bodies are brought near each other, and the *force* by which they adhere to one another, we cannot help thinking that he is miſtaken: For that bodies, chemically combined, are kept near each other by ſome force, cannot poſſibly be denied. Now, what is that force? We have ſaid, after Newton, an *attraction between the particles themſelves;* acknowledging, at the ſame time, that we are unable to explain what that is.

Count Rumford ſeems to ſuppoſe that there is no ſuch thing as attraction between the particles themſelves, but that caloric is the agent which keeps them together. If ſo, how does caloric perform this office? For our part, we do not pretend to underſtand it any more than the nature of attraction; nor do we ſee that it is poſſible to render it more intelligible. But there is another queſtion of ſtill greater importance, What are the proofs that caloric is the only agent in all caſes of chemical combinations? For our part, we can think of no proof that can render this opinion in the ſmalleſt degree plauſible.

Has this celebrated and candid philoſopher conſidered this ſubject with his uſual accuracy? If heat be a body, it cannot ſurely be the cauſe of affinity unleſs it be poſſeſſed of properties which, ſo far from being proved, have not even been ſuſpected. On the contrary, if it be a property of matter, what property is it? If it be a peculiar motion, as Count Rumford ſuſpects, we would aſk if it be poſſible for any motion whatever, independent of attraction, to produce the permanent union of two bodies?

* Weſtrum, n. de im. ii. 8.

† ch Wenzel? ... [illegible]fren, n. de im. xxiii.

‡ Fourcroy, n. de m. ii. 1.

PART III. OF DOUBLY COMPOUND BODIES.

THE bodies which conſiſt of combinations of thoſe ſubſtances that have been denominated *compound,* and which, for that reaſon, we have ventured to call *doubly compound bodies,* may be reduced to three claſſes:

Soaps,
Neutral ſalts,
Hydroſulphurets.

Theſe ſhall form the ſubject of the three following chapters; and we ſhall finiſh this part of the article with ſome obſervations on *cryſtallization.*

CHAP. I. *Of* SOAPS.

THE compounds into which *oils* enter without decompoſition have been denominated *ſoaps.*

Oils are capable of combining with alkalies, earths, and metallic oxyds; they are capable alſo of combining with ſeveral of the acids. There are therefore two claſſes of ſoaps; 1. Alkaline, earthy, and metallic ſoaps, which for the ſake of brevity we ſhall call *alkaline ſoaps;* and, 2. Acid ſoaps. Theſe two claſſes form the ſubject of the two following ſections.

SECT. I. *Of Alkaline Soaps.*

As there are a great number of oils, all or moſt of which are capable of combining with alkalies, earths, and oxyds, it is natural to ſuppoſe that there are as many genera of alkaline ſoaps as there are oils. That there are differences in the nature of ſoaps correſponding to the oil which enters into their compoſition, is certain; but theſe differences are not of ſufficient importance to require very particular deſcription. We ſhall therefore deſcribe all the alkaline ſoaps together, and notice, as we go along, ſome of the moſt important differences reſulting from the oily ingredients.

588
Common
hard ſoap.

1. Soap of ſoda, or common ſoap. The word *ſoap* (*ſapo,* σαπων) firſt occurs in the works of Pliny and Galen, and is evidently derived from the old German word *ſepe* (G). Pliny informs us, that ſoap was firſt diſcovered by the Gauls; that it was compoſed of tallow and

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(G) *Beckmann's Hiſtory of Inventions,* III. 239.—A ſimilar word is ſtill uſed by the common people of Scotland.

and aſhes; and that the German ſoap was reckoned the beſt.*

589 Method of forming it. Soap may be prepared by the following proceſs. A quantity of the ſoda of commerce, which is a carbonat of ſoda, and which is often called *barilla* from the name of a plant, by burning which it is procured in great quantities in Spain, is pounded and mixed in a wooden veſſel, with about a fifth part of its weight of lime, ſlacked and paſſed through a ſieve immediately before. Upon this mixture a quantity of water is poured, conſiderably more than what was ſufficient to cover it, and allowed to remain on it for ſeveral hours. The lime attracts the carbonic acid from the ſoda, and the water becomes ſtrongly impregnated with the pure alkali. This water is then drawn off by means of a ſtop-cock, and called the *firſt ley*. Its ſpecific gravity ſhould be about 1,200.

Another quantity of water is then to be poured upon the ſoda, which, after ſtanding two or three hours, is alſo to be drawn off by means of the ſtop-cock, and called the *ſecond ley*.

Another portion of water is poured on; and after ſtanding a ſufficient time, is drawn off like the other two, and called the *third ley*.

Another portion of water may ſtill be poured on, in order to be certain that the whole of the ſoda is diſſolved; and this weak ley may be put aſide, and employed afterwards in forming the firſt ley in ſubſequent operations.

A quantity of oil, equal to ſix times the weight of the ſoda uſed, is then to be put into the boiler, together with a portion of the *third* or *weakeſt ley*, and the mixture muſt be kept boiling and agitated conſtantly by means of a wooden inſtrument. The whole of the third ley is to be added at intervals to the mixture; and after it is conſumed, the *ſecond ley* muſt be added in the ſame manner. The oil becomes milky, combines with the alkali, and after ſome hours it begins to acquire conſiſtence. A little of the *firſt ley* is then to be added, not forgetting to agitate the mixture conſtantly. Portions of the firſt ley are to be added at intervals; the ſoapy ſubſtance acquires gradually greater conſiſtency, and at laſt it begins to ſeparate from the watery part of the mixture. A quantity of common ſalt is then to be added, which renders the ſeparation much more complete. The boiling is to be continued ſtill for two hours, and then the fire muſt be withdrawn, and the liquor muſt be no longer agitated. After ſome hours repoſe the ſoap ſeparates completely from the watery part, and ſwims upon the ſurface of the liquor. The watery part is then to be drawn off; and as it contains a quantity of carbonat of ſoda, it ought to be reſerved for future uſe.

The fire is then to be kindled again; and, in order to facilitate the melting of the ſoap, a little water, or rather weak ley, is to be added to it. As ſoon as it boils, the remainder of the firſt ley is to be added to it at intervals. When the ſoap has been brought to the proper conſiſtence, which is judged of by taking out ſmall portions of it and allowing it to cool, it is to be withdrawn from the fire, and the watery part ſeparated from it as before. It is then to be heated again, and a little water mixed with it, that it may form a proper paſte. It is then to be poured into the veſſels proper for cooling it; in the bottom of which there ought to be a little chalk in powder, to prevent the ſoap from attaching itſelf to it. In a few days the ſoap will have acquired ſufficient conſiſtence to be taken out, and formed into proper cakes (H).

The uſe of the common ſalt in the above proceſs is to ſeparate the water from the ſoap; for common ſalt has a ſtronger affinity for water than ſoap has.

Olive oil has been found to anſwer beſt for making ſoap, and next to it perhaps tallow may be placed: but a great variety of other oils may be employed for that purpoſe, as appears from the experiments of the French chemiſts above quoted. They found, however, that lintſeed oil and whale oil were not proper for making *hard ſoaps*, though they might be employed with advantage in the manufacture of *ſoft ſoaps*. Whale oil has been long uſed by the Dutch for this laſt purpoſe.

Soap may alſo be made without the aſſiſtance of heat; but in that caſe a much longer time and a larger proportion of alkali is neceſſary.

590 Its ſophiſtication. Manufacturers have contrived various methods of ſophiſticating ſoap, or of adding ingredients which increaſe its weight without increaſing its value. The moſt common ſubſtance uſed for that purpoſe is water; which may be added in conſiderable quantities, eſpecially to ſoap made with tallow (the ingredient uſed in this country), without diminiſhing its conſiſtency. This fraud may be eaſily detected, by allowing the ſoap to lie for ſome time expoſed to the air. The water will evaporate from it, and its quantity will be diſcovered by the diminution of the weight of the ſoap. As ſoap ſophiſticated in this manner would loſe its water by being kept, manufacturers, in order to prevent that, keep their ſoap in ſaturated ſolutions of common ſalt; which do not diſſolve the ſoap, and at the ſame time, by preventing all evaporation, preſerve, or rather increaſe, the weight of the ſoap. Meſſrs Darcet, Lelievre, and Pelletier, took two pieces equal in weight of ſoap ſophiſticated in this manner, and placed the one in a dry place in the open air, and the other in a ſaturated ſolution of common ſalt. After a month, the firſt had loſt $\frac{56}{100}$ of its weight, the other had gained about $\frac{10}{100}$ parts.* Various other methods have been fallen upon to ſophiſticate ſoap; but as they are not, we hope, generally known, it would be doing an injury to the public to deſcribe them here.

591 Proportion of its ingredients. Different chemiſts have analyſed ſoap, in order to aſcertain the proportions of its ingredients; but the reſult of their experiments is various, becauſe they uſed ſoap containing various quantities of water. From the experiments of Darcet, Lelievre, and Pelletier, it appears that ſoap newly made and expoſed to ſale contains

9,75	Oil,
1,37	Alkali,
4,87	Water.

Soap is ſoluble both in water and in alcohol. Its properties as a detergent are too well known to require any deſcription.

It

* Pliny, lib. xviii. c. 51.

* Ann. de Chim. xix. 336.

(H) See the *Memoir of Darcet, Lelievre, and Pelletier*, in the *Ann. de Chim.* XIX. 253.

lkaline oaps.

It is decompoſed by lime, and by compound affinity(1) by ſulphat of lime, nitrat of lime, muriat of lime, and probably all the ſalts which contain lime.

592 t ſoap.

2. Soap of potaſs. Potaſs may be ſubſtituted for ſoda in making ſoap, and in that caſe preciſely the ſame proceſs is to be followed. It is remarkable, that when potaſs is uſed, the ſoap does not aſſume a ſolid form; its conſiſtence is never greater than that of hog's lard. This is what in this country is called *ſoft ſoap*. Its properties as a detergent do not differ materially from thoſe of *hard ſoap*, but it is not nearly ſo convenient for uſe. The alkali employed by the ancient Gauls and Germans in the formation of ſoap was potaſs; hence we ſee the reaſon that it is deſcribed by the Romans as an unguent.

Some perſons have affirmed that they knew a method of making hard ſoap with potaſs. Their method is this: After forming the ſoap in the manner above deſcribed they add to it a large quantity of common ſalt, boil it for ſome time, and the ſoap becomes ſolid when cooled in the uſual way. That this method may be practiſed with ſucceſs has been aſcertained by Meſſrs Darcet, Lelievre and Pelletier; but then the hard ſoap thus formed does not contain potaſs but ſoda: for when the common ſalt (muriat of ſoda) is added, the potaſs of the ſoap decompoſes it, and combines with its muriatic acid, while at the ſame time the ſoda of the ſalt combines with the oil and forms hard ſoap: and the muriat of potaſs formed by this double decompoſition is diſſolved in the water and drawn off along with it*.

Ann. de im. xix. 2.

Chaptal has lately propoſed to ſubſtitute wool in place of oil in the making of ſoap. The ley is formed in the uſual manner and made boiling hot, and ſhreds of woollen cloth of any kind are gradually thrown into it; they are ſoon diſſolved. New portions are to be added ſparingly, and the mixture is to be conſtantly agitated. When no more cloth can be diſſolved, the ſoap is made†. This ſoap is ſaid to have been tried with ſucceſs. It might doubtleſs be ſubſtituted for ſoap with advantage in ſeveral manufactories, provided it can be obtained at a cheaper rate than the ſoaps at preſent employed.

Ann. de im. xxi.

Fiſh, too, have been lately ſubſtituted for oil with equal ſucceſs. The only diſadvantage which ſoap made in this manner is liable to, is a diſagreeable ſmell, from which it cannot eaſily be freed.

593 ap of nmonia.

3. Soap of ammonia. This ſoap was firſt particularly attended to by Mr Berthollet. It may be formed by pouring carbonat of ammonia on ſoap of lime. A double decompoſition takes place, and the ſoap of ammonia ſwims upon the ſurface of the liquor in the form of an oil; or it may be formed with ſtill greater eaſe by pouring a ſolution of muriat of ammonia into common ſoap diſſolved in water. We have formed it often by mixing cauſtic ammonia and oil*.

Berthollet, lem. Par. 780, or icholſon's ournal, i. 70.

It has a more pungent taſte than common ſoap. Water diſſolves a very ſmall quantity of it; but it is eaſily diſſolved in alcohol. When expoſed to the air, it is gradually decompoſed.

594 oap of me.

4. Soap of lime. This ſoap may be formed by pouring lime-water into a ſolution of common ſoap. It is inſoluble both in water and alcohol. Carbonat of fixed alkali decompoſes it by compound affinity†. It melts with difficulty, and requires a ſtrong heat.

Alkaline Soaps.

† Thouvenel.

595 Soap of magneſia,

5. Soap of magneſia. This ſoap may be formed by mixing together ſolutions of common ſoap and ſulphat of magneſia.

It is exceedingly white. It is unctuous, dries with difficulty, and preſerves its whiteneſs after deſiccation. It is inſoluble in boiling water. Alcohol and fixed oil diſſolve it in conſiderable quantity. Water renders its ſolution in alcohol milky. A moderate heat melts it; a tranſparent maſs is formed, ſlightly yellow, and very brittle*.

* Berthollet, ibid.

596 Of alumina,

6. Soap of alumina. This ſoap may be formed by mixing together ſolutions of alum and of common ſoap. It is a flexible ſoft ſubſtance, which retains its ſuppleneſs and tenacity when dry. It is inſoluble in alcohol, water and oil. Heat eaſily melts it, and reduces it to a beautiful tranſparent yellowiſh maſs†.

† Ibid.

597 Of barytes,

7. Soap of barytes reſembles almoſt exactly the ſoap of lime‡.

‡ Ibid.

598 Of mercury,

8. Soap of mercury.—This ſoap may be formed by mixing together a ſolution of common ſoap and of corroſive muriat of mercury. The liquor becomes milky, and the ſoap of mercury is gradually precipitated. This ſoap is viſcid, not eaſily dried, loſes its white colour when expoſed to the air, and acquires a ſlate colour, which gradually becomes deeper, eſpecially if expoſed to the ſun or to heat. It diſſolves very well in oil, but ſparingly in alcohol. It readily becomes ſoft and fluid when heated*.

* Ibid.

599 Of zinc.

9. Soap of zinc.—This ſoap may be formed by mixing together a ſolution of ſulphat of zinc and of ſoap. It is of a white colour, inclining to yellow. It dries ſpeedily, and becomes friable†.

† Ibid.

600 Of cobalt,

10. Soap of cobalt.—This ſoap made by mixing nitrat of cobalt and common ſoap is of a dull leaden colour, and dries with difficulty, though its parts are not connected.

601 Of nickel,

Mr Berthollet obſerved, that towards the end of the precipitation there fell down ſome green coagula, much more conſiſtent than ſoap of cobalt. Theſe he ſuppoſed to be a ſoap of nickel, which is generally mixed with cobalt‡.

‡ Ibid.

602 Of tin,

11. Soap of tin.—It may be formed by mixing common ſoap with a ſolution of tin in nitro-muriatic acid. It is white. Heat does not fuſe it like other metallic ſoaps, but decompoſes it||.

|| Ibid.

603 Of iron,

12. Soap of iron—Formed by means of ſulphat of iron.. It is of a reddiſh brown colour, tenacious, and eaſily fuſible. When ſpread upon wood, it ſinks in and dries. It is eaſily ſoluble in oil, eſpecially of turpentine. Berthollet propoſes it as a varniſh¶.

¶ Ibid.

604 Of copper,

13. Soap of copper—Formed by means of ſulphat of copper. It is of a green colour, has the feel of a reſin, and becomes dry and brittle. Hot alcohol renders its colour deeper, but ſcarcely diſſolves it. Ether diſſolves it, liquifies it, and renders its colour deeper and more beautiful. It is very ſoluble in oils, and gives them a pleaſant green colour§.

§ Ibid.

605 Of lead,

14. Soap of lead.—It may be formed by means of acetite

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(1) In this and the following chapter, *compound affinity* is not taken always in its ſtrict and proper ſenſe, but is applied to all thoſe decompoſitions in which the affinities of more than three bodies act.

wax, the firſt yellow, the laſt a deep brown. Nitre, ſal ammoniac, acetite of lead, iron filings, zinc powder, decompoſe it; vinegar, borax, filings of lead do not.

To unite this acid with the eſſential oils, three ounces were put into a glaſs mortar, and four ounces of the oil were added, drop by drop, and care taken to prevent its becoming hot: equal parts of water were then poured on, and the whole heated ſlowly nearly to the temperature of boiling water: on cooling, the ſoap united into a brown maſs.

22 Ol urpen- tir

8. Soap of ſulphuric acid and turpentine. It is brown, and of the conſiſtence of ſoft wax. Its ſolution in water is grey, opaque, viſcid; frothes: Its ſolution in alcohol is brown and tranſparent. Alkalies decompoſe it: with too much it forms at the boiling heat a new ſoap.

Nitric and muriatic acids ſeparated the oil thickened, as did alſo white oxyd of lead, muriat of lead, muriat of ſoda, and iron filings; but acetous acid, boracic acid, tartrite of potaſs, and tin filings, produced no ſuch effect.

of am- be il.

9. Soap of ſulphuric acid and amber oil.—Its ſolution in water and alcohol as in the laſt ſoap. Alkalies, magneſia, and lime, decompoſed it. Nitric and muriatic acids ſeparated the oil of the conſiſtence of wax. Tartar, ſal ammoniac, muriat of antimony, acetite of lead, iron filings, decompoſed it; vinegar, acetite of ammonia, and lead did not.

Mr Achard, to whom we owe theſe ſoaps†, could not ſucceed in his attempts to form ſoaps with nitric and muriatic acids.

CHAP. II. *Of* NEUTRAL SALTS.

524 S ex- pl ed.

THE word *ſalt* has been uſed in chemiſtry in a very extenſive, and not very definite ſenſe. Every body which is ſapid, eaſily melted, ſoluble in water, and not combuſtible, has been called a *ſalt*.

Salts were conſidered by the older chemiſts as a claſs of bodies intermediate between earths and water. Many diſputes aroſe about what bodies ought to be comprehended under this claſs, and what ought to be excluded from it. Acids and alkalies were allowed by all to be ſalts; but the difficulty was to determine concerning earth and metals. Several of the earths poſſeſs all the properties which have been aſcribed to ſalts; and the metals are capable of entering into combinations which poſſeſs ſaline properties. It is needleſs for us to enter into this diſpute at preſent, as we have taken the liberty, in imitation of ſome of the beſt modern chemiſts, to expunge the claſs of ſalts altogether, and to arrange thoſe ſubordinate claſſes, which are uſually referred to it, under diſtinct heads.

625 Neutral ſalt explained.

The word *neutral ſalt* was originally applied excluſively to combinations of acids and alkalies, which were conſidered as ſubſtances poſſeſſing neither the properties of acids nor alkalies, but properties intermediate between the two. But the word is now always taken in a more extenſive ſenſe, and ſignifies all compounds formed by the combination of acids with alkalies, earths, or metallic oxyds. In theſe compounds, the earth, alkali, or oxyd, is denominated the *baſe*. Each order of ſalts is denominated after the acid which enters into its compoſition; and every individual ſalt is diſtinguiſhed by ſubjoining the name of its baſe. Thus all the ſalts into which ſulphuric acid enters are called *ſulphats*, and the ſalt formed by the combination of ſulphuric acid and potaſs is called *ſulphat of potaſs*.

It is evident, then, that there muſt be as many orders of neutral ſalts as there are acids; and as many ſalts in each order as there are alkalies, earths, and metallic oxyds, ſuppoſing every acid capable of combining with every one of theſe ſubſtances. But beſides theſe ſimple combinations of one acid and one baſe, there are others more complex, compoſed of two acids combined with one baſe, or two baſes combined with one acid, or a neutral ſalt combined with an acid or a baſe. Theſe combinations have been called *triple ſalts*; and they increaſe the number of neutral ſalts very conſiderably.

In the following ſections we ſhall take a ſhort view of the properties of the principal neutral ſalts at preſent known; for this wide and important region of chemiſtry is ſtill very far from being completely explored.

SECT. I. *Of Sulphats.*

SULPHURIC acid is capable of combining with all the alkalies, with alkaline earths, alumina, jargonia, and the greater number of the metallic oxyds. The principal neutral ſalts which it forms are as follows:

626 Sulphat of potaſs.

1. Sulphat of potaſs.—This ſalt may be formed by ſaturating diluted potaſs with ſulphuric acid, and then evaporating the ſolution gently till cryſtals are formed. It ſeems to have been known at a very early period by chemiſts, and a great variety of names were given to it, according to the manner of forming it, or the fancy of the operator. Some of theſe names were, *ſpecificum purgans*, *nitrum fixum*, *arcanum duplicatum*, *panacea holſatica*, *ſal de duobus*, *ſal polychreſt glaſeri*, &c.; but it was commonly known by the name of *vitriolated tartar* till the French chemiſts called it *ſulphat of potaſs*, when they formed their new nomenclature in 1787 (K).

627 Its properties.

When the ſolution of ſulphat of potaſs is ſufficiently diluted, it affords by evaporation hexahedral pyramids, or ſhort hexangular priſms, terminated by one or more hexangular pyramids. But theſe cryſtals vary much in their figure, according to the care with which they are prepared.

It has a very diſagreeable bitter taſte. Its ſpecific gravity is 2,298*.

It is ſoluble in the temperature of 60° in 16 times its weight of water; in a boiling heat, it is ſoluble in 5 times its weight†.

According to Bergman, it is compoſed of 40 parts of acid, 52 parts of alkali, and 8 of water; but according to Kirwan, whoſe experiment has been already deſcribed, it is compoſed of 45 parts of acid and 55 of alkali.

It ſuffers no alteration in the air.

When placed upon burning coals, it breaks into pieces with a noiſe reſembling a number of ſmall exploſions ſucceeding each other at ſhort intervals (L), but ſuffers no other alteration. In a red heat it melts.

It has hitherto been applied to little uſe. It is a purgative,

† urn. de P . xvi. 4

* Briſſon.

† Bergman.

(K) Bergman called it *alkali vegetabile vitriolatum*, and Morveau *vitriol of potaſs*.

(L) This is called *decrepitation*.

purgative, but its diſagreeable taſte prevents it from being much employed for that purpoſe.

It often has an exceſs of acid, owing, as Mr Bergman and Morveau have very ingeniouſly explained, to an affinity which exiſts between this ſalt and ſulphuric acid.

It is decompoſed by compound affinity by the following ſalts:

Nitrat of ſoda (M),
———— lime,
———— barytes*,
———— ſtrontites‡,
———— ammonia,
———— magneſia,
———— mercury,

Nitrat of ſilver,
———— lead,
Acetite of barytes,
Muriat of lime†,
———— lead‖,
———— magneſia?
———— ſoda ¶.

* Kirwan.
‡ Id.
† Bergman.
‖ Id.
¶ Fuchs, Ann. de Chim. vi. 29.

It is ſometimes luminous in the dark, as Mr Giobert has obſerved*.

* Ann. de Chim. x. 40.

628 Sulphat of ſoda.

2. Sulphat of ſoda.—This ſalt was firſt diſcovered by Glauber a German chemiſt, and for that reaſon was long known by the name of *Glauber's ſalt*. He himſelf called it *ſal mirabile*. It may be prepared by ſaturating ſoda with ſulphuric acid, but is more uſually obtained by decompoſing common ſalt in order to procure muriatic acid.

Its cryſtals are tranſparent, and when formed by ſlow evaporation, are ſix-ſided priſms terminated by dihedral ſummits.

Its taſte at firſt has ſome reſemblance to that of common ſalt, but ſoon becomes very diſagreeably bitter.

It is ſoluble in 2,67 times its weight of water at the temperature of 60°, and in 0,8 of boiling water.

It is compoſed, according to Bergman, of 27 parts of acid, 15 of alkali, and 58 of water; but, according to the experiments of Kirwan, of 22 parts of acid, 17 of alkali, and 61 of water.

When expoſed to the air, it loſes great part of its water, and falls into a white powder (N).

When expoſed to heat it firſt undergoes the *watery fuſion* (O), then its water is evaporated, it is reduced to a white powder, and at laſt in a red heat it melts. Mr Kirwan has obſerved, that part of the acid, as well as the water, is driven off by the application of a ſtrong heat†.

‡ Iriſh Tranſ. iv.

This ſalt is uſed as a purgative.

It often combines with an exceſs of acid.

It is decompoſed by compound affinity by the following ſubſtances.

Nitrat of lime,
———— magneſia,
Muriat of potaſs,
———— ſoda,
———— magneſia,
———— lime‡.

Acetite of barytes,
———— potaſs,
———— lime,
Carbonat of barytes,
———— potaſs,

‡ Scheele,

629 Sulphat of ammonia.

3. Sulphat of ammonia.—This ſalt was diſcovered by Glauber, and called by him *ſecret ſal ammoniac*. It was alſo called *vitriolated ammoniac*. It may be prepared by ſaturating ammonia with ſulphuric acid.

Its cryſtals are generally ſmall ſix-ſided priſms, whoſe planes are unequal, terminated by ſix-ſided pyramids.

It has a ſharp bitter taſte.

It is ſoluble in twice its own weight of water at the temperature of 60°, and in its own weight of boiling water.

According to Mr Kirwan, it is compoſed of 29,7 of alkali, 55,7 of ſulphuric acid, and 14,16 of water‖.

‖ Iriſh Tranſ.

When expoſed to the air, it ſlowly attracts moiſture.

When heated, it firſt decrepitates, then melts, and in cloſe veſſels ſublimes, but with ſome loſs of its alkali†.

† Kirw Minera ii. 11.

It has not hitherto been applied to any uſe.

It is apt to contain an exceſs of acid.

It is decompoſed by compound affinity by the following ſalts:

Nitrat of lime,
———— magneſia,
———— mercury?
Muriat of potaſs,
———— ſoda,
———— barytes,
———— lime,
———— magneſia.
———— mercury*,
Acetite of potaſs,

Acetite of ſoda,
———— barytes,
———— lime,
———— magneſia,
Carbonat of potaſs,
———— ſoda,
———— barytes,
———— lime,
———— magneſia,
Phoſphat of lime†.

* Berg
† Delkeſ Ann. de Chim. 37.

63 Sulpha barytes

4 Sulphat of barytes. This ſubſtance was firſt diſcovered by Scheele. It abounds in nature. It is generally in the form of a hard very heavy ſtone.

It is ſometimes found cryſtallized; but the variety of forms is ſo great that they baffle all deſcription.

It is ſoluble in 43,000 times its weight of water at the temperature of the atmoſphere*.

* Kirw Minera i. 136.

Sulphuric acid diſſolves it when concentrated and boiling, but it is precipitated by the addition of water.

When expoſed to heat it melts, and, if the heat be very ſtrong, gradually diſſipates.

631 Bologn ſtone.

After being heated red hot, it has the property of being luminous in the dark. This was firſt obſerved in a variety of this ſubſtance known by the name of Bologna ſtone. Lemery informs us, that this property was firſt diſcovered by an Italian ſhoemaker named Vincenzo Caſciarolo. This man found a Bologna ſtone at the foot of Mount Paterno, and its brightneſs and gravity made him ſuppoſe that it contained ſilver. Having expoſed it to the fire, doubtleſs in order to extract from it the precious metal, he obſerved that it was luminous in the dark. Struck with the diſcovery, he repeated the experiment, and it conſtantly ſucceeded with him.

From an experiment of Mr Klaproth, it appears to be compoſed of 33 parts of acid and 77 of barytes.

It is decompoſed by compound affinity by the following ſalts:

Nitrat of ſoda,
———— lime,
———— ammonia,

Nitrat of magneſia,
Carbonat of potaſs,
———— ſoda*.

* Afzw

63 Sulpha lime.

5. Sulphat of lime. This ſubſtance was well known to the ancients under the name of *gypſum*; but the compoſition of gypſum was not known till Margraf and Macquer analyſed it, and proved that it was compoſed of ſulphuric acid and lime. The artificial compound

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(M) Moſt of theſe double decompoſitions in this and the following ſections are inſerted on the authority of Morveau. See his table of *Affinity*, page 399 of this article.

(N) This is called *efloreſcing*.

(O) When ſubſtances melt by means of the water they contain on the application of heat, they are ſaid to undergo the watery fuſion.

ſtood with accuracy. It has been long known, indeed, that one of its ingredients is ſulphuric acid (R); and the experiments of Geoffroy, Hellot, Pott, Margraf, and Macquer, proved inconteſtibly that alumina is another ingredient. But ſulphuric acid and alumina are incapable of forming alum: Manufacturers knew, that the addition of a quantity of potaſs, or of ammonia, or of ſome ſubſtance containing theſe alkalies, is almoſt always neceſſary; and it was proved, that in every caſe in which ſuch additions are unneceſſary, the earth from which the alum is obtained contained already a quantity of potaſs. Various conjectures were made about the part which potaſs acts in this caſe; but Chaptal and Vauquelin appear to have been the firſt chemiſts that aſcertained by deciſive experiments that alum was a triple ſalt, compoſed of ſulphat of alumina and of potaſs united together (S).

640 And properties.

Alum cryſtallizes in large octahedrons, compoſed of two tetrahedral pyramids, applied to each other at their baſes.

It has a ſweetiſh and aſtringent taſte, and always reddens the tincture of turnſol.

It is ſoluble at the temperature of 60°, in from 10* to 15† times its own weight of water, according to its purity; pure alum being moſt inſoluble. Seventy-five parts of boiling water diſſolve 100 of alum ‡.

* *Neumann and Chaptal.*
† *Kirwan and Chaptal.*
‡ *Bergman.*

A hundred parts of alum contain, according to Kirwan, 17,62 parts of acid, 18 of earth (and alkali), and 64,38 of water ||.

|| *Kirwan's Min.* ii. 14.

When expoſed to the air it effloreſces ſlightly.

When expoſed to a gentle heat it undergoes the watery fuſion. A ſtrong heat cauſes it to ſwell and foam, and to loſe about 44 *per cent.* of its weight, conſiſting chiefly of water of cryſtallization §. What remains is called *calcined* or *burnt alum*, and is ſometimes uſed as a corroſive.

§ *Ibid.*

Alum is of great importance as a mordant in dyeing, and is uſed alſo in ſeveral other arts.

By compound affinity it is decompoſed by the following ſalts.

Nitrat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
Muriat of barytes,
——— potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia.
Acetite of barytes,

Acetite of potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia,
Carbonat of barytes,
——— potaſs,
——— ſoda,
——— lime,
——— ammonia,
——— magneſia.

641 Homberg's pyrophorus.

If three parts of alum and one of flour or ſugar be melted together in an iron ladle, and the mixture dried till it becomes blackiſh and ceaſes to ſwell; if it be then pounded ſmall, put into a glaſs phial, and placed in a ſand-bath till a blue flame iſſues from the mouth of the phial, and after burning for a minute or two be allowed to cool (T), a ſubſtance is obtained known by the name of *Homberg's pyrophorus*, which has the property of catching fire whenever it is expoſed to the open air, eſpecially if the air be moiſt.

This ſubſtance was accidentally diſcovered by Homberg about the beginning of the 18th century, while he was engaged in his experiments on the human fæces. He had diſtilled a mixture of human fæces and alum till he could obtain nothing more from it by means of heat; and four or five days after, while he was taking the reſiduum out of the retort, he was ſurpriſed to ſee it take fire ſpontaneouſly. Soon after Lemery the Younger diſcovered that honey, ſugar, flour, or almoſt any animal or vegetable matter, could be ſubſtituted for human fæces; and afterwards Mr Lejoy de Suvigny ſhewed that ſeveral other ſalts containing ſulphuric acid might be ſubſtituted for alum.* Scheele proved, that alum deprived of potaſs was incapable of forming pyrophorus, and that ſulphat of potaſs might be ſubſtituted for alum †. And Mr Prouſt has ſhewn, that a number of neutral ſalts, compoſed of vegetable acids and alkalies, or earths, when diſtilled by a ſtrong fire in a retort, left a reſiduum which took fire ſpontaneouſly on expoſure to the air.

* See
quer's
† *Schee*
Fire, a
Pyroph

Theſe facts have thrown a great deal of light on the nature of Homberg's pyrophorus, and enabled us in ſome meaſure to account for its ſpontaneous inflammation. It has been aſcertained, that part of the ſulphuric acid is decompoſed during the formation of the pyrophorus, and of courſe a part of the alkaline baſe becomes uncombined with acid, and the carbon, which gives it its black colour, is evidently divided into very minute particles. It has been aſcertained, that during the combuſtion of the pyrophorus a quantity of oxygen is abſorbed. The inflammation ſeems to be owing to a *diſpoſing affinity*. Part of the carbon and of the ſulphur attract oxygen from the atmoſphere, in order to combine with the potaſs, and the caloric diſengaged produces a temperature ſufficiently high to kindle the reſt of the carbon.

Alum is capable of combining with alumina, and of forming what has been called *alum ſaturated with its earth*, which is an inſoluble, taſteleſs, earthy-like ſubſtance.

It is capable alſo, as Chaptal informs us, of combining with ſeveral other baſes, and of forming many triple ſalts, which have never yet been examined with attention.*

* *Ann*
11. *Chimie* xii.
293.

(R) Some chemiſts have thought proper to call the ſulphuric acid, obtained by diſtilling alum, *ſpirit of alum.*

(S) This they did in the two memoirs above quoted, and which were firſt publiſhed in the 22d volume of the *Annales de Chimie*. An account of Vauquelin's memoir has been already given under the article ALUM in this *Supplement*. Chaptal's memoir is no leſs intereſting. This celebrated chemiſt appears, from the facts ſtated in the 23d volume of the *Annales*, p. 222. to have made his diſcovery before Vauquelin; who, however, was ignorant of what Chaptal had done, as he informs us in the *Ann. de Chim.* xxv. 107. that his paper was read to the Inſtitute a fortnight before that of Chaptal's came to Paris. He informs us, too, that Deſcroiſilles had long before made the ſame diſcovery, and that he had publiſhed it in Berthollet's *Art de la Teinture.*

(T) Care muſt be taken not to keep it too long expoſed to the heat.

ulphats.

642
lphat of
gonia.

11. Sulphat of jargonia (U). In order to combine jargonia with acids, they ſhould be poured upon it while it is yet moiſt, after being precipitated from ſome of its ſolvents; for after it is dry, acids do not act upon it without difficulty. By this method ſulphat of jargonia is eaſily formed. It is white, and without ſenſible taſte. Heat expels the acid from it, and the jargonia remains in a ſtate of purity. At a high temperature charcoal converts it into a ſulphuret, which is ſoluble in water, and which, by evaporation, furniſhes cryſtals of hydroſulphuret (T) of jargonia +.

Vauque-
, Ann. de
im. xxii.
9.

Klaproth informs us, that with exceſs of acid ſulphat of jargonia forms tranſparent ſtelliform cryſtals, ſoluble in water, and having an aſtringent taſte †.

Journ. de
yſ. xxxvi.
7.

12. Sulphat of iron. There are two ſulphats of iron, which were firſt accurately diſtinguiſhed by Mr Prouſt. The one contains the green oxyd, the other the red oxyd of iron. We ſhall, in imitation of Mr Prouſt, denominate them from their colours.

643
reen ſul-
ıat of iron.

The *green ſulphat of iron*.—This ſalt, which is compoſed of ſulphuric acid and green oxyd of iron, is found native, and was known to the ancients. It is mentioned by Pliny under the names of *miſy*, *ſory*, *calchantum*.* It was formerly called *green vitriol*.

*Lib.*xxxiv.
12.

It is generally prepared by expoſing native ſulphuret of iron, a very abundant mineral, to air and moiſture.

Its cryſtals are of a light green colour, and in the form of rhomboidal parallelopipeds.

It has a ſharp aſtringent taſte.

It is ſoluble in ſix times its weight of water at the temperature of 60°, and in $\frac{4}{5}$ths of its weight of boiling water †.

Bergman.

It is inſoluble in alcohol.

According to Bergman, it is compoſed of 39 parts of acid, 23 of oxyd, and 38 of water; but according to Mr Kirwan, of 26 parts of acid, 28 (U) of oxyd, and 46 of water.

Sulphats.

When expoſed to the air, it effloreſces; but if it be moiſtened, it is gradually converted into red ſulphat of iron.

When heated, it firſt aſſumes a yellow colour, loſes its water and its acid; if the heat be increaſed, nothing remains but a yellow powder.

The Pruſſic alkali precipitates from the ſolution of this ſalt a white powder, which gradually becomes blue by attracting oxygen §.

§ *Prouſt.*

It is uſed in dyeing, and in making ink, &c.

It is decompoſed by compound affinity, by

Nitrat of ſilver,
Muriat of ſoda.*

* *Ballen and Tuthen, Ann. de Chim.* xi. 520.

The *red ſulphat of iron* may be formed by expoſing a ſolution of green ſulphat to the air, or by treating it with nitric acid. It was formerly called *mother water of vitriol*.

644
Red ſulphat
of iron.

Little is known of its properties, except that it is deliqueſcent, incryſtallizable, and ſoluble in alcohol.

It was firſt accurately examined by Mr Prouſt.

The green ſulphat of iron generally contains ſome of it, which may be ſeparated by means of alcohol.

It is alone capable of forming Pruſſian blue with the Pruſſic acid, and of ſtriking a black colour with the gallic acid †.

† See *Prouſt's paper, Nicholſon's Journal*, i. 453.

We have obſerved, that when it is diluted with water, and an exceſs of ſulphuric acid is poured in, it is again ſlowly converted into green ſulphat.

645
Sulphat of
zinc.

13. Sulphat of zinc.—This ſalt, according to the beſt accounts, was diſcovered at Rammelſberg in Germany, about the middle of the 16th century. Many

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(U) *Jargonia*, or, as the French chemiſts call it, *zirconia*, has been diſcovered in great abundance in France by Morveau, who found that the hyacinths of Expailly contained more than half their weight of it. From Vauquelin's analyſis they appear to be compoſed of

32 parts	of ſilica,
64	jargonia,
2	oxyd of iron.

Jargonia has been examined with great care by theſe two philoſophers, the experiments of Klaproth have been confirmed, and ſeveral new properties of it have been diſcovered. Perhaps a more detailed account than we have hitherto given of this new earth may not be unacceptable to our readers.

Jargonia is a white powder, its ſpecific gravity is conſiderable, it has a feel reſembling that of ſilica, it has no taſte, and is inſoluble in water. When ſeparated from its ſolutions by pure alkalies, it retains, when expoſed to the air to dry, a pretty conſiderable quantity of water, which renders it tranſparent, and gives it a reſemblance to gum arabic both in its colour and fracture.

When expoſed to the heat of the blow-pipe it does not melt; but Vauquelin melted it by expoſing it ſurrounded with charcoal in a porcelain crucible to an intenſe heat for an hour and a half. Its ſpecific gravity was then 4,35, its colour was grey, and its hardneſs ſuch that it was capable of ſcratching glaſs. It melts with borax, and forms a tranſparent and colourleſs glaſs; but phoſphat of ſoda and the fixed alkalies do not attack it.

It is inſoluble in the fixed alkalies, has very little affinity for carbonic acid, and is precipitated from its ſolutions together with iron by the Pruſſic alkali.

Its affinities, as far as they have been aſcertained by Vauquelin, are as follows:

Vegetable acids, order unknown,
Sulphuric acid,
Muriatic,
Nitric.

See upon this ſubject the Memoirs of Morveau and Vauquelin, *Ann. de Chim.* xxi. 72, and xxii. 179.

(T) Theſe curious ſalts form the ſubject of the next chapter.

(U) Perhaps the quantity of oxyd is ſomewhat over-rated here; for before it was examined by Mr Kirwan, it had aſſumed a red colour: it muſt therefore have been converted into the brown or red oxyd by attracting oxygen from the atmoſphere.

is precipitated ; for the triple ſalt is rendered much more ſoluble by an exceſs of ammonia. As this exceſs evaporates, the ſalt cryſtallizes. The cryſtals are polygons, very brilliant and hard. It has a ſharp, auſtere, metallic taſte. It has no peculiar odour. It is ſcarcely ſoluble, except with exceſs of ammonia. It is compoſed, according to Fourcroy's analyſis, of 18 parts of ſulphuric acid, 33 of ammonia, and 39 of oxyd of mercury. Heat decompoſes it. The products obtained by diſtilling it are, a little ammonia, azotic gas, a little pure mercury, ſome *ſulphite of ammonia* ; and there remains yellow ſulphat of mercury.*

This triple ſalt may be formed alſo by pouring ammonia upon acidulous ſulphat of mercury, or on yellow ſulphat of mercury†.

657 Sulphat of ſilver. 26. Sulphat of ſilver.—This ſalt is formed by pouring ſulphuric acid on oxyd of ſilver. Its cryſtals are ſmall needles. It melts when expoſed to a ſtrong heat, but does not ſublime.

It is decompoſed by muriat of lead‡.

27. Sulphat of gold.—This ſalt is unknown.

28. Sulphat of platinum.—Unknown.

29. Sulphat of tungſten.—Probably no ſuch combination is poſſible.

30. Sulphat of molybdenum.—Probably impoſſible.

658 Sulphat of uranium, 31. Sulphat of uranium.—This ſalt was firſt formed by Mr Klaproth. He formed it by pouring ſulphuric acid on the oxyd of uranium. Nothing farther is known of it, except that its cryſtals are ſmall, and of a yellow colour.

659 Titanium, 32. Sulphat of titanium.—This ſalt was firſt formed by Mr M'Gregor. It does not appear, from Klaproth's experiments, to be cryſtallizable.

660 Tellurium. 33. Sulphat of tellurium.—When one part of tellurium is mixed cold in a well ſtopped veſſel with an hundred parts of concentrated ſulphuric acid, the latter gradually aſſumes a beautiful crimſon red colour : when a ſmall quantity of water is added, drop by drop, the colour diſappears, and the metal is precipitated in the form of black flakes. The ſolution is deſtroyed by heat, the colour diſappears, and the metal ſeparates in the ſtate of a white oxyd. When ſulphuric acid is diluted with two or three parts of water, and a ſmall quantity of nitric acid is added, it diſſolves a conſiderble quantity of tellurium. The ſolntion is tranſparent and colourleſs, and is not decompoſed by the addition of a larger quantity of water‡.

Sect. II. *Of Sulphites.*

Salts compoſed of ſulphurous acid united reſpectively with alkalies, earths, or oxyds, are called *ſulphites*. Thoſe hitherto examined are the following :

661 Sulphite of potaſs. 1. Sulphite of potaſs.—This ſalt was firſt formed by Stahl ; but was firſt accurately deſcribed by Berthollet, Fourcroy, and Vauquelin.

It may be formed by paſſing ſulphurous acid into a ſaturated ſolution of carbonat of potaſs till all effervescence ceaſes. The ſolution becomes hot, and cryſtallizes by cooling.*

Its cryſtals are white and tranſparent ; their figure that of rhomboidal plates. Its cryſtallization often preſents ſmall needles diverging from a common centre†.

Its taſte is penetrating and ſulphurous. At the common temperature of the atmoſphere, it is ſoluble in its own weight of water, but much more ſoluble in boiling water.

When expoſed to the air, it effloreſces, becomes opaque and hard, and is gradually converted into *ſulphat of potaſs* by abſorbing oxygen.

When expoſed to a ſudden heat, it decrepitates, loſes its water : at a red heat ſome ſulphurous vapours are emitted ; at laſt a portion of ſulphur ſeparates, and the reſiduum is ſulphat of potaſs, with a ſlight exceſs of alkali.

Nitric and oxy-muriatic acids convert it into ſulphat of potaſs by imparting oxygen.

It decompoſes the oxyds of gold, ſilver, mercury, the red oxyd of lead, the black oxyd of mangaueſe, and the brown oxyd of iron. When the green oxyd of iron and the white oxyd of iron are boiled with it in water, and an acid added, a precipitate takes place of theſe bodies united to ſome ſulphur, and the ſalt is converted into a ſulphat : at the ſame time ſulphurated hydrogen gas is emitted.

By compound affinity it is decompoſed by

All ſalts with baſe of ſoda, except the borat and carbonat ;

All metallic ſalts except carbonats ;

All neutral ſalts whoſe acid has a ſtronger affinity for potaſs than ſulphurous acid has†.

662 Sulphite of ſoda. 2. Sulphite of ſoda.—This ſalt was firſt accurately deſcribed by Fourcroy and Vauquelin.

It is white and perfectly tranſparent. Its cryſtals are four-ſided priſms, with two very broad ſides and two very narrow ones, terminated by dihedral pyramids.

Its taſte is cool and ſulphurous.

It is ſoluble in four times its weight of cold water, but it is more ſoluble in hot water.

It is compoſed of 18,8 parts of ſoda, 31,2 of acid, and 50 of water.

By expoſure to air, it effloreſces, and is ſlowly converted into a ſulphat.

When expoſed to heat, it undergoes the watery fuſion, and afterwards exhibits preciſely the ſame phenomena as the ſulphite of potaſs.

Metallic oxyds and ſalts affect it preciſely as they do ſulphite of potaſs.

It is decompoſed by compound affinity by carbonat of potaſs, and the other ſalts which decompoſe ſulphite of potaſs||.

663 Sulphite of ammonia. 3. Sulphite of ammonia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin¶.

It cryſtallizes in ſix-ſided priſms terminated by ſix-ſided pyramids.

Its taſte is cool and penetrating like that of the other ammoniacal ſalts, but it leaves a ſulphurous impreſſion in the mouth.

It is ſoluble in its own weight of cold water. Its ſolubility is increaſed by heat.

It is compoſed of 29,07 parts of ammonia, 60,06 of acid, and 10,87 of water.

When expoſed to the air, it attracts moiſture, and is ſoon converted into a ſulphat.

Heat volatilizes it without decompoſition.

Its habitudes with metallic oxyds and ſalts are nearly the ſame with thoſe of the above deſcribed ſulphites, only it is capable of forming with ſeveral of them triple ſalts†.

664 Sulphite of barytes. 4. Sulphite of barytes.—This ſalt was firſt deſcribed by Berthollet‡.

It is incryſtallizable ; it has no perceptible taſte ; and is perfectly inſoluble in water*.

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* *Fourcroy, ibid.*

† *Ibid.*

‡ *Bergman.*

‡ *Klaproth, Philoſophical Mag.* i. 80.

* *Fourcroy, and Vauquelin, Nicholſon's Jour.* i. 317.

† *Ibid.*

† *Ibid.*

|| *Ibid.*

¶ *Fourcroy and Vauquelin, Nicholſon's Jour.* i. 317.

† *Ibid.*

‡ *Ann. de Chim.* ii. 57.

* *Fourcroy and Vauquelin.*

It is compoſed of 59 parts of barytes, 39 parts of acid, and 2 of water.

It does not eaſily change into a ſulphat by expoſure to air; but heat produces this effect‡.

665 **Sulphite of lime.** 5. Sulphite of lime.—This ſalt was firſt deſcribed by Berthollet||.

Its cryſtals are ſix-ſided priſms, terminated each by a very long pyramid*.

It has ſcarcely any taſte; however, when kept long in the mouth, it communicates to the tongue a taſte which is manifeſtly ſulphurous.

It is very ſparingly ſoluble in water, except with exceſs of acid.

It is compoſed of 47 parts of lime, 48 of ſulphurous acid, and 5 of water.

By contact of air it is converted into a ſulphat, but very ſlowly.

Heat converts it into a ſulphat by depriving it of a portion of ſulphur.

It is decompoſed by compound affinity by

Carbonats of alkalies,	Fluats of alkalies,
Phoſphats of alkalies,	Moſt metallic ſalts*.

666 **Sulphite of magneſia.** 6. Sulphite of magneſia.—This ſalt was firſt deſcribed by Fourcroy and Vauquelin.

Its cryſtals are white and tranſparent, and in the form of depreſſed tetrahedrons.

Its taſte is mild and earthy at firſt, and afterwards ſulphurous.

It is ſparingly ſoluble in water, except when there is an exceſs of acid.

It is compoſed of 16 parts of magneſia, 39 of acid, and 45 of water.

It becomes opake when expoſed to the air; is very ſlowly converted into a ſulphat.

By expoſure to heat, it ſoftens, ſwells up, and becomes ductile like gum; a ſtrong heat decompoſes it altogether.

It is decompoſed by
Alkaline ſalts,
Earthy ſalts, except thoſe of alumina†.

667 **Sulphite of alumina.** 7. Sulphite of alumina.—Firſt formed by Berthollet.

It does not cryſtallize, but is converted into a ſoft ductile maſs. It is not ſoluble in water, but becomes abundantly ſo when there is an exceſs of acid.

It is compoſed of 44 parts of alumina, 32 of acid, and 24 of water.

Heat decompoſes it¶.

668 **Sulphite of iron.** 8. Sulphite of iron.—It was firſt formed by Berthollet.

Its cryſtals are white, and have but very little of the ſtyptic taſte of iron ſalts*.

Berthollet alſo formed the ſulphites of zinc and tin, but he has not deſcribed them.

SECT. III. *Of Nitrats.*

THOSE ſalts, in the compoſition of which the nitric acid forms one ingredient, are called *nitrats*.

669 **Nitre.** 1. Nitrat of potaſs, nitre, or ſaltpetre.—As this ſalt is produced naturally in conſiderable quantities, particularly in Egypt, it is highly probable that the ancients were acquainted with it; but ſcarcely any thing certain can be collected from their writings. If Pliny mentions it at all, he confounds it with ſoda, which was known by the names of *nitron* and *nitrum*. It is certain, however, that it has been known in the eaſt from time immemorial. Roger Bacon mentions this ſalt in the 13th century under the name of *nitre*.

It cryſtallizes in ſlender oblong hexagonal priſms, often ſtriated, terminated by hexagonal pyramids obliquely truncated. Its ſpecific gravity is 1,920.

Its taſte is ſharp, bitteriſh, and cooling.

It is ſoluble in ſeven times its weight of water at the temperature of 60°, and in nearly its own weight of boiling water†.

According to Bergman, it is compoſed of 31 parts of acid, 61 of potaſs, and 8 of water; but this proportion of acid is undoubtedly too ſmall. According to Mr Kirwan, it is compoſed of 41,2 of acid, 46,15 of alkali, and 12,65 of water‡.

It is not altered by expoſure to the air.

When expoſed to a ſtrong heat, it melts; and congeals by cooling into an opake maſs, which has been called *mineral cryſtal.* If the heat be continued, the acid is gradually decompoſed and driven off. When the ſolution of nitre is expoſed to a boiling heat, part of the ſalt is evaporated along with the water, as Wallerius, Kirwan, and Lavoiſier, obſerved ſucceſſively. When nitre is expoſed to heat along with many combuſtible ſubſtances, its acid is decompoſed; the combuſtible ſeizes the oxygen, and at the ſame time a lively white flame appears, attended with a decrepitation: this is called the *detonation of nitre.*

Nitre mixed with charcoal and ſulphur in proper proportions forms *gunpowder.*

Nitre is decompoſed by compound affinities by
Acetite of barytes.

670 **Reprodu tion of i tre.** No phenomenon has excited the attention of chemical philoſophers more than the continual reproduction of nitre in certain places after it had been extracted from them. Prodigious quantities of this ſalt are neceſſary for the purpoſes of war; and as Nature has not laid up great magazines of it as ſhe has of ſome other ſalts, this annual reproduction is the only ſource from which it can be procured. It became, therefore, of the utmoſt conſequence, if poſſible, to diſcover the means which Nature employed in forming it, in order to enable us to imitate her proceſſes by art, or at leaſt to accelerate and facilitate them at pleaſure. Numerous attempts accordingly have been made to explain and to imitate theſe proceſſes.

Stahl, ſetting out on the principle that there is only one acid in nature, ſuppoſed that nitric acid is merely ſulphuric acid combined with phlogiſton; and that this combination is produced by putrefaction: he affirmed accordingly, that nitre is compoſed by uniting together potaſs, ſulphuric acid, and phlogiſton. But this opinion, which was merely ſupported by very far-fetched analogies, could not ſtand the teſt of a rigorous examination.

Lemery the Younger accordingly advanced another; affirming, that all the nitre obtained exiſts previouſly in animals and vegetables, and that it is formed in theſe ſubſtances by the proceſſes of vegetation and animalization. But it was ſoon diſcovered that nitre exiſts, and is actually formed, in many places where no animal nor vegetable ſubſtance had been decompoſed; and conſequently this theory was as untenable as the former. So far indeed is it from being true that nitre is formed alone by theſe proceſſes, that the quantity of nitre in plants has been found to depend entirely on the ſoil in which they grow*.

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‡ *Ibid.*

|| *Ann. de Chim. ibid.*

* *Fourcroy and Vauquelin.*

* *Ibid.*

† *Fourcroy and Vauquelin.*

¶ *Fourcroy and Vauquelin.*

* *Ann. de Chim.* ii. 58.

† *Bergma*

‡ *Minera* ii. 27.

* *Bouill*

It is decompoſed by heat.

By compound affinity it is decompoſed by

Sulphat of barytes,
——— potaſs,
——— ſoda,
——— ammonia,
——— alumina,
Muriat of barytes,
——— potaſs,
——— ſoda,
Muriat of lime,
Acetite of barytes,
——— potaſs,
——— ſoda,
——— lime,
Carbonat of barytes,
——— potaſs,
——— lime.

677 Nitrat of ammonia and magneſia.

8. Nitrat of ammonia and magneſia. This triple ſalt was diſcovered by Mr Fourcroy. Into a ſaturated ſolution of nitrat of magneſia, containing 73 grains of magneſia, he poured ammonia as long as any precipitate could be obtained. Twenty-one grains of magneſia were precipitated, 52 grains remained combined with the acid and the ammonia. He found that 52 grains of magneſia produced, when ſaturated with nitric acid, 288 grains of nitrat; and that the quantity of nitric acid neceſſary to ſaturate 21 grains of magneſia, when ſaturated with ammonia, produced 84 grains of nitrat of ammonia. He concludes, therefore, though the data are not quite ſatisfactory, that the triple ſalt is compoſed of 288 grains of nitrat of magneſia, and 84 of nitrat of ammonia*.

678 Nitrat of alumina.

9. Nitrat of alumina. This ſeems to have been firſt attended to by Baumé.

Its cryſtals are pyramidal. It has a very aſtringent taſte. It is ſoluble in water, and deliqueſces in the air.

679 Nitrat of jargonia.

10. Nitrat of jargonia. This ſalt may be eaſily formed by pouring nitric acid on newly precipitated jargonia.

It always contains an exceſs of acid. By evaporation a yellowiſh tranſparent matter is obtained, exceedingly tenacious and viſcid, and which dries with difficulty. It has an aſtringent taſte, and leaves on the tongue a viſcid matter, owing to its being decompoſed by the ſaliva. It is only very ſparingly ſoluble in water; the greateſt part remains under the form of gelatinous and tranſparent flakes. Like all the other ſalts into which jargonia enters, it is decompoſed by heat. It is decompoſed alſo by ſulphuric acid, which occaſions a white precipitate, ſoluble in exceſs of acid; by carbonat of ammonia, which produces a precipitate ſoluble by adding more carbonat; and by an infuſion of nut galls in alcohol, which produces a white precipitate ſoluble in an exceſs of the infuſion, unleſs the jargonia contains iron, in which caſe the precipitate is a greyiſh blue, and part of it remains inſoluble, giving the liquor a blue colour. This liquor, mixed with carbonat of ammonia, produces a matter purple by tranſmitted light, but violet by reflected light. Gallic acid alſo precipitates nitrat of jargonia of a greyiſh blue, but the colour is not ſo fine. Moſt of the other vegetable acids decompoſe this ſalt, and form combinations inſoluble in water†.

680 Nitrat of iron.

11. Nitrat of iron. The green oxyd of iron decompoſes, but does not combine with nitric acid. The brown oxyd forms with it a red or brown ſolution, which by evaporation may be reduced to a jelly, but will not cryſtallize.

681 Nitrat of zinc.

12. Nitrat of zinc. The oxyd of zinc combines with nitric acid, and forms with it a ſalt which cryſtallizes in compreſſed and ſtriated tetrahedral priſms, terminated by four-ſided pyramids.

Its ſolution is exceedingly cauſtic. When placed on burning coals, it melts and detonates as it dries. It can ſcarcely be dried without being in ſome meaſure decompoſed.

It deliqueſces in the air*.

13. Nitrat of mangane‌ſe. This ſalt, compoſed of oxyd of mangane‌ſe and nitric acid, was firſt examined by Scheele. Its cryſtals are ſmall and ſhining, of a very bitter taſte, and ſoluble in water†.

14. Nitrat of cobalt. It is of a pale red colour, and cryſtallizes in needles. It deliqueſces when expoſed to the air. Heat decompoſes it. When nickel is preſent, this ſalt aſſumes a green colour.

15. Nitrat of nickel. Its cryſtals are of a green colour, and in the form of rhomboidal cubes. They are deliqueſcent, and are gradually decompoſed when expoſed to the air, the acid leaving them‡.

16. Nitrat of lead. Nitric acid combines with the white oxyd of lead. The cryſtals of this ſalt are of a white colour; their form an irregular octagon, or rather truncated hexahedral pyramid. When expoſed to heat it decrepitates, and melts with a yellowiſh flame. By compound affinity it is decompoſed by

Muriat of potaſs,
——— ſoda,
——— ammonia,
Carbonat of ſoda§.

17. Nitrat of tin. Tin is converted into an acid by nitric acid. It is not probable, therefore, that any permanent nitrat of tin can be formed.

18. Nitrat of copper. This ſalt appears to have been firſt obtained by Macquer.

Its form, when properly cryſtallized, is an oblong parallelogram. It is of a fine blue colour. It is exceedingly cauſtic. It melts at 77°¶.

It is deliqueſcent in a moiſt air, but in a dry place is covered with a green efflorescence. It is very ſoluble in water. Heat decompoſes it.

19. Nitrat of biſmuth. This ſalt cryſtallizes in various forms. Fourcroy obtained it in flattened rhomboids. It effloreſces in the air. Water decompoſes it. It detonates in the fire.

20. Nitrat of antimony. Little is known concerning this ſalt, except that it is very deliqueſcent, and is decompoſed by heat.

21. Nitrat of arſenic. With white oxyd of arſenic nitric acid forms a ſalt which cryſtallizes. It is very deliqueſcent. It does not detonate.

22. Nitrat of mercury. This ſalt may be formed by diſſolving mercury in nitric acid. It cryſtallizes in the cold in regular flat 14-ſided figures; but their form differs according to the manner in which the cryſtallization has been performed.

It is ſoluble in water.

This ſalt is exceedingly cauſtic. It detonates on coals. When heated in a crucible it melts, and is decompoſed. The oxyd attracts oxygen from the acid, which flies off in the form of nitrous gas, and red oxyd of mercury remains behind.

It is ſlowly decompoſed alſo in the air. It is decompoſed by compound affinity by

Sulphat of copper, and a great many other ſulphats,
Phoſphat of ſoda,
Borax.

23. Nitrat of ammonia and mercury. This triple ſalt may be formed by pouring ammonia into a ſolution of

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* Ann. de Chim. iv. 215.

† Vauquelin, Ann. de Chim. xxii. 199.

* Fou

† Sch

‡ Ber ii. 26

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¶ Sa

uriats.

of nitrat of mercury. If only enough of ammonia to ſaturate the acid be uſed, the triple ſalt precipitates in the form of a white powder; but with an exceſs of ammonia it remains diſſolved, and forms by evaporation very bright polyhedral cryſtals.

It has a very ſharp taſte. It is ſoluble in 1200 parts of water at the temperature of 55°. Hot water ſeparates a little ammonia which renders it ſtill more inſoluble. It turns vegetable blues green. Muriatic acid diſſolves it.

According to Fourcroy's analyſis, it is compoſed of 68,20 parts of oxyd of mercury, 16 of ammonia, and 15,80 of nitric acid and water.

When diſtilled it yields ammonia, azotic gas, oxygen gas, yellow oxyd of mercury, and pure mercury.*

urcroy, de . xiv.

'93 at of r,

24. Nitrat of ſilver. This ſalt may be formed by diſſolving ſilver in nitric acid.

It forms flat tranſparent cryſtals compoſed of needles. It is exceedingly cauſtic. When melted it forms a grey maſs called *lapis infernalis*, from its great corroſiveneſs.

It is very ſoluble in water. It is not altered by expoſure to the air. Light decompoſes it.

By compound affinity it is decompoſed by

The ſulphats,
The muriats.

'94 t of ium,

25. Nitrat of uranium. This ſalt was firſt formed by Klaproth. Its cryſtals are hexagonal plates of a greeniſh yellow colour. The largeſt were $\frac{3}{4}$ths of an inch in length and $\frac{1}{4}$th in breadth †.

aproth, n. de xxxvii.

'95 ium,

26. Nitrat of titanium. It is capable of cryſtallizing.

'96 rium.

27. Nitrat of tellurium. The ſolution of tellurium in nitric acid is tranſparent and colourleſs. When concentrated, it produces in time ſmall white light cryſtals in the form of needles, which exhibit a dendritic aggregation ‡.

aproth, Mag.

Sect. IV. *Of Nitrites.*

The ſalts which the nitrous acid forms with alkalies, earths, and metallic oxyds, are denominated *nitrites*. Very few of them have been examined; we ſhall not therefore attempt a deſcription of them.

Sect. V. *Of Muriats.*

Salts into which the muriatic acid enters are called *muriats*.

'97 iat of tafs.

1. Muriat of potaſs. This ſalt was formerly called *febrifuge* or *digeſtive ſalt of Sylvius*, and *regenerated ſea ſalt*.

Its cryſtals are cubes, but rather irregular.

It has a diſagreeable bitter taſte. Its ſpecific gravity is 1,836 §.

rwan.

It is ſoluble in three times its weight of water at the temperature of 60°, and in double its weight of boiling water ¶.

rgman.

It is compoſed, according to Bergman, of 31 parts of acid, 61 of potaſs, and 8 of water. Kirwan has found it to contain 36 of acid, 46 of alkali, and 18 of water ‖.

rwan's eral. i. o.

It ſuffers little alteration from expoſure to the air.

When expoſed to heat, it firſt decrepitates, then melts, and at laſt is volatilized, but without decompoſition.

The following ſalts decompoſe it by compound affinity:

Sulphat of ſoda,
——— ammonia,
——— alumina,
Nitrat of ſoda,
——— lime,

Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead.

Muriats.

698 Muriat of ſoda.

2. Muriat of ſoda, common or ſea ſalt. This ſalt has been known, and in common uſe, from the earlieſt ages. It is ſometimes called alſo *ſal gem*.

Its cryſtals are cubes, but they often aſſume other forms. Its ſpecific gravity is 2,120.*

* *Kirwan.*

Its taſte is univerſally known, and is what is ſtrictly ſpeaking denominated *ſalt*.

It is ſoluble in $2\frac{14}{17}$ times its weight of water at the temperature of 60°, and in $2\frac{13}{17}$ its weight of boiling water †.

† *Bergman.*

According to Bergman, it is compoſed of 52 parts of acid, 42 of alkali, and 6 of water. According to the late experiments of Mr Kirwan, of 40 parts of acid, 35 of alkali, and 25 of water.

It is not affected by expoſure to the air. It ought to be obſerved, however, that the muriat of ſoda in common uſe contains, beſides other impurities, a quantity of muriat of magneſia, which renders it deliqueſcent.

When heated it decrepitates. Heat volatilizes, but does not decompoſe it.

The following ſalts decompoſe it by compound affinity:

Sulphat of ammonia,
——— alumina,
——— potaſs,*
——— iron †,
Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead ‡,

Nitrat of ſilver §,
Acetite of barytes,
Pyrolignite of barytes ‖,
——— lead ‖,
Carbonat of potaſs (*a*),
Alum (*b*),
Red oxyd of lead (*c*).

* *Fuchs, Ann. de Chim.* vi. 29.
† *Bullen, ibid.* xi. 320.
‡ *Morveau.*
§ *Bergman.*
‖ *Morveau. Ann. de Chim.* xix. 109.
(*a*) *Bergman*
(*b*) *Crell, Ann. de Chim.* xxvi. 297.
(*c*) *Scheele.*

699 How decompoſed by red oxyd of lead.

That the red oxyd of lead decompoſes this ſalt is a well known fact, and it has been conſidered as contrary to the laws of affinity. Mr Haſſenfratz endeavoured to account for it by ſuppoſing that the oxyd is combined with carbonic acid, and that therefore it is a caſe of compound affinity. Mr Curaudau has proved that carbonic acid, inſtead of promoting, impedes the decompoſition; and that, in fact, carbonat of lead is incapable of decompoſing muriat of ſoda. He concludes, therefore, that the phenomenon cannot be accounted for by the commonly received laws of affinity.* We cannot, however, think, that the phenomenon is ſo unaccountable as Mr Curaudau ſuppoſes; for muriatic acid is capable of decompoſing the red oxyd of lead, of combining with part of its oxygen, and of being converted into oxy-muriatic acid. Now if oxy-muriatic and nitro-muriatic acids be merely the ſame ſubſtance in a different form, as there is the ſtrongeſt reaſon for ſuppoſing, the white oxyd of lead has a ſtronger affinity for it than ſoda has, and ought therefore to decompoſe it.

* *Ann. de Chim.* xiv. 15.

700 Muriat of ammonia.

3. Muriat of ammonia, or ſal ammoniac. This ſalt was known to the ancients, and was called by them *ſal ammoniac*, becauſe it was found in great quantities near the temple of Jupiter Ammon in Africa.*

* *Pliny*, lib. xxxi. c. 7. See *Sal Ammoniac*, Encyc.

It aſſumes the form of plumoſe cryſtals. The individual cryſtals are long hexahedral pyramids. Its ſpecific gravity is 1,420 †.

† *Kirwan.*

It has an acrid, poignant, urinous taſte.

It diſſolves in about three times its weight of water at the temperature of 60°, and in a much ſmaller quantity of boiling water.

It is compoſed, according to Kirwan, of 35 parts of acid, 30 of alkali, and 45 of water ‡.

‡ *Kirwan's Mineral.* ii. 34.

In its common form (which is an opaque maſs) it is not affected by the air, but its cryſtals are liable to deliqueſce.

Heat volatilizes without decompoſing it.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,
Nitrat of ſoda,
——— lead,
Acetite of barytes,
——— potaſs,
——— ſoda,
——— lime,
Acetite of magneſia,
——— alumina,
——— lead,
Carbonat of barytes,
——— potaſs,
——— magneſia (Y)

When this ſalt is ſublimed with gold leaf, there is found in the neck of the retort an amethyſt coloured matter, bordering on purple, ſoluble in water, and forming a purple ſolution. When filtered there remains behind a purple powder. This ſalt ſeems from this to be capable of oxydating gold.*

701 Muriat of barytes,

4. Muriat of barytes. This ſalt was firſt deſcribed by Bergman, but it has been moſt particularly attended to by Dr Crawford.

It affords oblong ſquare cryſtals.

It has an unpleaſant aſtringent taſte.

It is not very ſoluble in water. It is ſoluble in alcohol.

It is not altered by expoſure to the air, nor does heat in all probability decompoſe it.

Dr Crawford wrote a treatiſe on it in 1790, in which he recommended its uſe internally for ſcrofulous complaints. Care ought to be taken not to give it in too large quantities, as, like the other compounds of barytes, it is poiſonous.

The following ſalts decompoſe it by compound affinity (Z):

Sulphat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
Nitrat of lime,
——— ammonia,
——— magneſia,
——— alumina,
Phoſphat of lime.*

702 Muriat of ammonia and barytes,

5. Muriat of ammonia and barytes. This triple ſalt was firſt diſcovered by Fourcroy. It may be formed by pouring a carbonat of ammonia into a ſolution of muriat of barytes. It is eaſily decompoſed by heat, but none of the alkalies nor their carbonats are capable of altering it †.

703 Muriat of lime,

6. Muriat of lime. This ſalt was formerly called *fixed ammoniac*, becauſe it was commonly obtained by decompoſing ſal ammoniac by means of lime.

Its cryſtals are four-ſided ſtriated priſms, terminated by a very ſharp pyramid; but it is not eaſily cryſtallized.

Its taſte is very bitter.

It is ſoluble in about 1½ parts of cold water, and in leſs than its own weight of boiling water. Alcohol diſſolves its own weight of it.

According to Bergman, it is compoſed of 31 parts of acid, 44 of lime, and 25 of water. According to Kirwan, 100 parts of lime require for ſaturation 86 parts of muriatic acid.

It very ſpeedily deliqueſces when expoſed to the air. Mu

By heat it melts into a very hard vitreform ſubſtance.

The following ſalts decompoſe it by compound affinity:

Sulphat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Carbonat of potaſs,
——— ſoda,
——— ammonia,*
——— barytes,
——— magneſia,
——— alumina,
Acetite of barytes,
——— potaſs,
——— ſoda.

7 Muri ſtron

7. Muriat of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are very long, ſlender, hexagonal priſms. It has a peculiar, ſharp, penetrating taſte.

Three parts of theſe cryſtals are ſoluble in two parts of water at the temperature of 60°. Boiling water diſſolves any quantity of them whatever.

They contain 42 *per cent.* of water of cryſtallization.

They ſuffer no change when expoſed to the air except it be very moiſt; in which caſe they deliqueſce.

When heated, they firſt undergo the watery fuſion, and are then reduced to a white powder. A very violent heat decompoſes this ſalt.

Muriatic acid precipitates this ſalt from its ſolution in water. That acid, therefore, has a ſtronger affinity for water than the ſalt has.*

Mu mag

8. Muriat of magneſia. This ſalt abounds in ſea water.

It is not eaſily cryſtallized. Bergman's method was to evaporate it by a conſiderable heat to the proper degree of concentration, and then to expoſe it to a ſudden cold. By this method he obtained it in ſmall needles †.

It has a very bitter taſte. It is ſoluble in its own weight of water ‡, and in five parts of alcohol §.

A ſaturated ſolution of it quickly forms a jelly; on which if hot water be poured, ſpongy maſſes are formed not even ſoluble in muriatic acid.*

It is compoſed, according to Bergman, of 34 parts of acid, 41 of earth, and 25 of water. According to Kirwan, 100 parts of magneſia require for ſaturation 104,275 of acid †.

It deliqueſces very ſpeedily when expoſed to the air.

A ſtrong heat decompoſes it. When dried in a high temperature, it is very cauſtic ‡.

The following ſubſtances decompoſe it by compound affinity:

Sulphat of ſoda,
——— ammonia,
——— alumina,
Nitrat of ammonia,
Acetite of potaſs,
——— ſoda,
——— ſilver,*

Carbonat

* Storr, *Crell's New Diſcoveries*, &c. Part ii. p. 41.

* *Dr Pearſon.*

† *Ann. de Chim.* iv. 8.

* *Ber*

* *H*
Tra
iv. 1

† *Be*
ii. 3

‡ *Fo*

§ *B*
ii. 3

* *B.*
ibid.

† *I*
Tra

‡ *W*
Ann.
Chi
135

* *E*

(Y) Only at the common temperature. At a high temperature carbonat of ammonia decompoſes muriat of magneſia. See *Weſtrum*, *Ann. de Chim.* ii. 118.

(Z) Bergman affirmed, that this ſalt decompoſed all the ſulphats, and propoſed it therefore as a certain means of diſcovering the preſence of ſulphuric acid, however combined in any ſolution; for the ſulphat of barytes is almoſt entirely inſoluble in water. But Mr Piſſis has obſerved, that it does not decompoſe ſulphat of lime nor of potaſs. See *Ann de Chim.* xv. 317.

Carbonat of barytes,
———— potaſs,
Carbonat of ſoda,
———— ammonia (y)

706 riat of monia mag- a,

9. Muriat of ammonia and magneſia. This triple ſalt was firſt mentioned, we believe, by Bergman. It may be formed by pouring ammonia into a ſolution of muriat of magneſia. Part of the magneſia is precipitated, but great part of it remains diſſolved, and combined with the acid and the ammonia. This triple ſalt is compoſed according to Fourcroy, of 73 parts of muriat of magneſia and 27 of muriat of ammonia[†].

707 riat of ina,

10. Muriat of alumina. This ſalt cryſtallizes with difficulty. It has an aſtringent taſte. Its ſolution is gelatinous, and cannot be filtrated without much dilution in water. It is deliqueſcent. When evaporated to dryneſs, it forms a gummy maſs: in a ſtrong heat it is decompoſed.

The following ſalts decompoſe it by compound affinity:

Nitrat of ammonia,
Acetite of barytes,
———— potaſs,
———— ſoda,
———— lime,
Acetite of magneſia,
Carbonat of barytes,
———— potaſs,
———— ſoda,
———— ammonia.

708 iat of onia,

11. Muriat of jargonia.—This ſalt is eaſily formed by pouring muriatic acid on newly precipitated jargonia. It is colourleſs; its taſte is very aſtringent: by evaporation it furniſhes ſmall tranſparent cryſtals in needles, which loſe their tranſparence in the air. Muriat of jargonia is very ſoluble in water and in alcohol; to the flame of which it does not communicate any particular colour. Heat decompoſes it; and it is decompoſed likewiſe by the ſaliva when taken into the mouth.

When muriat of jargonia contains a little ſilica, it forms cubic cryſtals without conſiſtence, and reſembling a jelly. Theſe cryſtals, when expoſed to the air, gradually loſe their tranſparency, and diminiſh in volume, and there are formed in the middle of the ſalt white ſilky needle-ſhaped cryſtals.

Muriat of jargonia is decompoſed by ſulphuric acid; part of the ſulphat precipitates, and part remains diſſolved in the muriatic acid. When this acid is driven off by heat, the remainder of the ſulphat is gradually depoſited: if the evaporation be ſtopped before the maſs be reduced to dryneſs, it forms a kind of jelly when cold. It is alſo decompoſed by the phoſphoric, citric, tartarous, oxalic and ſaccholactic acids, which form with jargonia inſoluble compounds that precipitate in white flakes.

The gallic acid poured into muriat of jargonia produces a white precipitate; but a green, bordering on grey, if the jargonia contain iron; and this laſt precipitate becomes, when dry, of a bright black colour, and reſembles China ink. The liquid preſerves a greeniſh colour; new portions of gallic acid produce no farther precipitation; but carbonat of ammonia ſeparates in great abundance a flaky matter of a purpliſh colour, not unlike that of the leys of wine. From theſe experiments it follows, that gallic acid has a greater affinity for jargonia than muriatic acid has; and that the gallats of jargonia and iron are ſoluble in muriatic acid.

Carbonat of potaſs decompoſes muriat of jargonia, and part of the carbonic acid combines with the earth, and renders it eaſily ſoluble in acids though dried.

Carbonat of ammonia occaſions a precipitate, which is moſtly diſſolved by adding more carbonat.

Pruſſiat of mercury produces an abundant precipitate, which is ſoluble in muriatic acid; and which conſequently is not muriat of mercury.

A plate of zinc, introduced into a ſolution of muriat of jargonia, occaſions a ſlight efferveſcence; the liquor becomes milky, and in a few days becomes a white ſemitranſparent jelly.

Alumina decompoſes muriat of jargonia with the aſſiſtance of a ſlight heat: the alumina diſſolves, the liquor becomes milky, and aſſumes the form of a jelly. When the muriat contains iron, it remains in the ſolution, and the precipitated jargonia is quite pure. Here, then, is a method of freeing jargonia from iron.*

709 Muriat of iron,

12. Muriat of iron.—Muriatic acid forms with the green oxyd of iron a ſalt which cryſtallizes in flat needles. When expoſed to the air, they deliqueſce, and the green oxyd attracts oxygen, and is gradually converted into a brown oxyd. Heat decompoſes this ſalt.

710 Muriat of zinc,

13. Muriat of zinc. This ſalt, procured by diſſolving zinc or its oxyd in muriatic acid, does not cryſtallize. Its ſolution is colourleſs. When heated, it becomes of a blackiſh brown. By diſtillation, a part of the acid is ſeparated, and muriat of zinc remains behind of a milk white colour, ſolid, and formed of ſmall radiated needles. It attracts moiſture in the air.

711 Muriat of manganeſe,

14. Muriat of manganeſe. Muriatic acid diſſolves the white oxyd of manganeſe. Its ſolution affords by evaporation angular ſhining cryſtals[†]: They are deliqueſcent and ſoluble in alcohol[‡].

712 Cobalt,

15. Muriat of cobalt. The ſolution of oxyd of cobalt in muriatic acid is of a pale red, except it be contaminated with nickel or iron, when it is greeniſh. It cryſtallizes in ſmall needles, which are very deliqueſcent. Heat decompoſes it.

713 Nickel,

16. Muriat of nickel. This ſalt is deliqueſcent, and loſes its acid when expoſed to the air[¶].

714 Lead,

17. Muriat of lead. Muriatic acid combines with oxyd of lead eaſily enough: but this ſalt is more readily procured by pouring muriatic acid into a ſolution of nitrat of lead; the muriat immediately precipitates in the form of a white powder. It is ſoluble in 30 times its weight of boiling water; and the ſolution yields by evaporation ſmall, ſlender, brilliant needles in bundles. It is ſomewhat deliqueſcent. When expoſed to heat, it melts into a brown maſs, formerly called *corneous lead*.

It is decompoſed by compound affinity by
Sulphat of ſilver*,
Carbonat of ſoda.

715 Tin,

18. Muriat of tin. This ſalt may be formed by diſſolving tin in hot muriatic acid. By evaporation, it affords needle-ſhaped cryſtals, which are deliqueſcent.

This ſalt has a ſtrong affinity for oxygen. It decompoſes oxy-muriatic, nitric, ſulphurous, arſenic, molybdic and tungſtic acids, the red oxyd of mercury, black oxyd of manganeſe, oxyd of antimony, zinc, ſilver,

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[†] nn. de Ch. iv.

* *Vauquelin, Ann. de Chim.* xxii. 201.

[†] *Scheele on Manganeſe.*

[‡] *Kirwan's Mineral.* ii. 37.

[¶] *Bergman*, ii. 268.

* *Bergman.*

(y) Only at a high temperature. See *Muriat of Ammonia.*

ty-muriats.

of mercury. Berthollet firſt pointed out the nature of its compoſition.

This ſalt was mentioned by Rhaſes in the 10th century. And it ſeems to have been known in the eaſt at a much earlier period(A). The methods of preparing it uſed by the older chemiſts, were numerous, complicated, and generally concealed as ſecrets. We ſhall not attempt, therefore, to give any account of them; and the methods uſed by later chemiſts have been deſcribed at conſiderable length in the article CHEMISTRY (*Encycl.* n° 815).

It may be prepared by diſſolving mercury in a ſufficient quantity of oxy-muriatic acid, or by diſſolving red oxyd of mercury in common muriatic acid.

When carefully cryſtallized, this ſalt aſſumes the form of cubes or oblique parallelopipeds, or rather quadrangular priſms, with ſides alternately narrower and terminated by two inclined planes meeting together.

It has an exceedingly diſagreeable metallic taſte.

It is ſoluble in 19 times its weight of water at the temperature of 50°‡. Boiling water, according to Macquer, diſſolves half its weight of it. Alcohol, at the temperature of 70°, diſſolves $\frac{3}{8}$ths of its weight of this ſalt.*

‡ Spielman.

* Macquer.

It does not attract moiſture from the air.

It is ſoluble in ſulphuric, nitric and muriatic acids.

When triturated with $\frac{3}{4}$ths of its weight of mercury and a little water, and then ſublimed, it forms a white inſipid ſalt, called formerly *calomel* or *ſweet mercury*: This, as Scheele has proved, is preciſely the ſame with common muriat of mercury.

The theory of theſe two preparations is now pretty obvious. The experiments of Adet and Pelletier have ſhewn that oxy-muriatic acid may be obtained from corroſive muriat of mercury¶. We may conclude, therefore, with confidence, that the ſalt is an oxy-muriat. It cannot be prepared by means of common muriatic acid, except with red oxyd of mercury, or ſome other ſubſtance from which it may abſorb oxygen. When pure mercury is added to oxy-muriat, it ſeizes the oxygen from the oxy-muriat, and the whole is converted into common muriat.

¶ Ann. de im. i. 1. d xii. 5.

It is decompoſed by

Tartar,
Moſt metals.

728
xy-muriat of tin,

8. Oxy-muriat of tin. When an amalgam of tin is triturated with its own weight of corroſive muriat of mercury, and the mixture is diſtilled in a glaſs retort by means of a very gentle heat, there paſſes over a thick white ſmoke, which condenſes into a colourleſs liquor that emits copious fumes, and has been called, in conſequence, *ſmoking liquor of Libavius*. This liquor was examined by Mr Adet. He found, that when about $\frac{1}{3}$d part of water was added to this liquor, it ceaſed to fume, and aſſumed a cryſtalline form; that then it might be even made red hot without ſubliming. It therefore owes its volatility to want of water, or rather to a ſtrong attraction for water. He found that this ſubſtance was capable of diſſolving, and therefore of oxydating more tin, without the emiſſion of any hydrogen, and conſequently without the decompoſition of water; he concluded from this, that it was compoſed of oxy-muriatic acid and tin§. This has been completely proved by Mr Pelletier, who found, that when oxyd of tin was combined with oxy-muriatic acid, it formed a compound preciſely the ſame with the ſmoking liquor of Libavius*.

Phoſphats.

§ Ann. de Chim. i. 3.

* Ann. de Chim. xii. 225.

This ſalt may be prepared, as Pelletier has proved, by diſſolving tin in muriatic acid, and then ſaturating it with oxy-muriatic acid gas.

It is uſed in dyeing.

729
Oxy-muriat of iron,

9. Oxy-muriat of iron. This ſalt is deliqueſcent; colourleſs; of a pure bitter taſte, without any of the ſweet aſtringency of the common ſalts of iron||.

|| Lambe, Mancheſter Mem. v. p. 1.

Few of the other oxy-muriats have been hitherto examined with attention. Many of the metals, indeed, have been diſſolved in aqua-regia; but in moſt of theſe ſolutions the ſalt produced is a common muriat. The nitric acid ſupplies oxygen, and the muriatic acid diſſolves the oxyd.

SECT. VII. *Of Phoſphats.*

THOSE ſalts, into which phoſphoric acid enters as an ingredient, are called *phoſphats*. This claſs of ſalts was firſt diſcovered by Margraf.

730
Phoſphat of potaſs,

1. Phoſphat of potaſs. This ſalt cryſtallizes in ſhort tetrahædral priſms, terminated by quadrangular pyramids.

It is very ſoluble in cold water, and ſtill more ſo in hot water.

It decrepitates on ignited coals like common ſalt. When a very ſtrong heat is applied, it melts into an opaque vitreous maſs, ſtill ſoluble in water.

The following ſalts decompoſe it by compound affinity:

Sulphat of lime, Muriat of mercury,
Nitrat of mercury, Acetite of lead.

731
Phoſphat of ſoda,

2. Phoſphat of ſoda.—Dr Pearſon, who firſt formed this ſalt, gives the following proceſs for preparing it:

Diſſolve in a long-necked matraſs 1400 grains of cryſtallized carbonat of ſoda in 2100 grains of water at the temperature of 150°. Add gradually 500 grains of phoſphoric acid of the ſpecific gravity 1,85. Boil the liquor for ſome minutes; and while it is boiling hot, filtrate it and pour it into a ſhallow veſſel. Let it remain in a cool place, and cryſtals will continue to form for ſeveral days. From the above quantities of materials, he has obtained from 1450 to 1550 grains of cryſtals.

Its cryſtals are rhomboidal priſms, of which the acute angles are 60°, and the obtuſe angles 120°, terminated by a three-ſided pyramid.

Its taſte is almoſt the ſame with that of common ſalt.

It is ſoluble in water. When expoſed to the air it effloreſces.

This ſalt has been introduced into medicine as a purgative, and on account of its pleaſant taſte has of late been much uſed. It is uſually taken in broth, which it is employed to ſeaſon inſtead of common ſalt.

Hellot remarked a particular ſalt in urine, different from thoſe that had uſually been obſerved, in 1737. Haupt deſcribed it in 1740 under the name of *ſal mirabile*

(A) If we liſten to Juncker, the ancients applied the name *mercurium* to this ſalt; mercury they called *argentum vivum*.

Borats.

4. Borat of barytes.—Unknown.

748 lime,
5. Borat of lime.—It is difficultly ſoluble in water, and did not cryſtallize with Beaumé.

749 ſtron-
es,
6. Borat of ſtrontites.—This ſalt was firſt formed by Dr Hope.—It is a white powder, ſoluble in about 130 parts of boiling water. The ſolution turns the ſyrup of violets green*.

750 magne-
7. Borat of magneſia.—It aſſumes the appearance of ſmall irregular cryſtals. It is ſoluble in acetous and formic acids. Alcohol decompoſes it. It melts eaſily in the fire without being decompoſed‡.

751 alumi-
8. Borat of alumina.—It does not cryſtallize, and is ſcarcely ſoluble in water.

752 iron,
9. Borat of iron.—Its cryſtals are of a yellow colour, but the ſalt has never been examined with attention.

753 zinc,
10. Borat of zinc.—This ſalt does not appear to be capable of cryſtallizing.—By heat, it melts into a light green inſoluble ſlag¶.

754 balt,
11. Borat of cobalt.—When oxyd of cobalt is melted with boracic acid, a bluiſh grey ſlag is produced. This, by lixiviation and evaporation, yields cryſtals of a reddiſh white colour and ramified form§.

755 ckel,
12. Borat of nickel.—A ſaline ſubſtance difficultly ſoluble*.

756 Lead,
13. Borat of lead.—When boracic acid and red oxyd of lead are melted together, the product is a fine greeniſh yellow, tranſparent, hard, inſoluble glaſs‡.

757 Tin,
14. Borat of tin.—When equal parts of boracic acid and tin filings are melted together, the product diſſolved in water yields by evaporation tranſparent white polygonous cryſtals.

758 Copper,
15. Borat of copper.—When borax is poured into a ſolution of ſulphat of copper, borat of copper is precipitated in the form of a pale light green jelly, which when dried is with great difficulty ſoluble in water. It eaſily melts into a dark red vitreous ſubſtance*. According to Palm, by long trituration of filings of copper and boracic acid in water, and then digeſting the mixture, it diſſolves, and cryſtals may be obtained from it.

759 ſmuth,
16. Borat of biſmuth.—A white powder, which melts into a white tranſparent permanent glaſs†.

760 ſenic.
17. Borat of arſenic.—White oxyd of arſenic and boracic acid form a ſalt ſoluble in water and cryſtallizable*.

Hope, anſ. Edin. i 17.
Bergman, 386.
Reuſs.
d.
Bergman.
Reuſs.
Bergman.
Wenzel.
Reuſs.

SECT. IX. *Of Fluats.*

761 uat of taſs,
THOSE ſalts into which fluoric acid enters are called *fluats*. They were firſt formed by Scheele.

1. Fluat of potaſs. It forms a gelatinous maſs almoſt without taſte.

It diſſolves readily in water. When expoſed to the fire it melts without any ebullition‡.

762 Soda,
2. Fluat of ſoda. This ſalt reſembles exactly the fluat of potaſs†.

763 mmonia,
3. Fluat of ammonia. It cryſtallizes in ſmall priſms. It is deliqueſcent, and is partly decompoſed by heat*.

It is decompoſed by

Nitrat of mercury,
——— ſilver,
——— lead.

764 rytes,
4. Fluat of barytes. A powder which requires a large quantity of water to diſſolve it*.

765 Lime,
5. Fluat of lime. This ſalt abounds in nature. It is known by the name of fluor ſpar.

It cryſtallizes moſt commonly in the form of cubes. It is taſteleſs and nearly inſoluble in water.

Fluats.

It is not altered by the air. Its ſpecific gravity is about 3,1.

When expoſed to a ſudden heat it decrepitates. A very violent heat melts it into a white opaque maſs.

When reduced to powder and heated it becomes phoſphoreſcent; but it loſes this quality altogether if it be heated red hot.

6. Fluat of ſtrontites. This ſalt was formed by Dr Hope: but its properties have not been examined.

766 Magneſia,
7. Fluat of magneſia. It is not ſoluble in water except there be an exceſs of acid. In that caſe, by ſpontaneous evaporation, it forms hexagonal priſms, terminated by a low pyramid compoſed of three rhomboidal ſides.

Theſe cryſtals are hardly ſoluble in water. Alcohol diſſolves a ſmall portion of them. Heat does not decompoſe them†.

767 Alumina,
8. Fluat of alumina. A ſaline maſs; which is ſweetiſh, clammy, and gelatinous.

768 Silica,
9. Fluat of ſilica. Little is known concerning this ſingular combination, except that it can exiſt in a gaſeous form, and that it depoſites ſilica in cryſtals after a certain time.

10. Fluat of ſilica and potaſs or ſoda. This triple ſalt may be formed by pouring fixed alkali into a ſolution of fluat of ſilica. It contains an exceſs of acid. On evaporation it yields a kind of jelly, which when dry ſeparates into gritty particles like ſand. It is ſoluble in 96 parts of hot water. In the fire it readily melts into a white maſs. If the heat be continued the acid ſeparates, and there remains a tranſparent glaſs, which is ſoluble in water, and forms a *liquor ſilicum*‡.

769 Metallic fluats.
11. Fluat of iron. It is incryſtallizable; but when evaporated leaves a hard maſs.

12. Fluat of zinc. It reſembles that of iron.

13. Fluat of mangneſe. It may be formed by pouring fluat of ammonia into a ſolution of oxyd of zinc in any of the three mineral acids. It cryſtallizes.

14. Fluat of cobalt. A yellow gelatinous maſs.

15. Fluat of nickel. It affords green cryſtals.

16. Fluat of lead. A ſweet taſted powder.

17. Fluat of tin. A nauſeous taſted jelly.

18. Fluat of copper. Blue cryſtals; ſome of them oblong, others cubic.

19. Fluat of arſenic. Small cryſtals.

20. Fluat of mercury. A powder. Before the blowpipe it melts into a yellow glaſs, moſt of which evaporates by a continued heat§.

† *Bergman*, ii. 384.
‡ *Scheele*, *Crell's Journal*, i. 207. Eng. tranſl.
§ *Scheele* on *Fluor.*

SECT. X. *Of Carbonats.*

THE compounds into which the carbonic acid enters are called *carbonats*. They were firſt analyſed by Dr Black.

670 Carbonat of potaſs.
1. Carbonat of potaſs. This ſalt is formed by ſaturating potaſs with carbonic acid, which is beſt done by expoſing a ſolution of potaſs for a conſiderable time to carbonic acid gas.

It cryſtallizes, according to Bergman, in quadrangular priſms; the apexes of which are compoſed of two inverted triangles, converging like the roof a houſe*. According to Pelletier they are tetrahedral rhomboidal priſms, with dihedral ſummits. The complete cryſtal has eight faces, two hexagons, two rectangles, and four rhombs†.

Scheele on uor.
Ibid.
Wiegleb.
Bergman.

* *Bergman.*
† *Ann. de Chim.* xv. 29.

It has an alkaline, but not a cauſtic taſte.

It is ſoluble at the common temperature in about four times its weight of water‡. Boiling water diſſolves ⅚ths of its weight§. Alcohol, even when hot, does not diſſolve above $\frac{1}{1200}$ parts of it.

According to Bergman, it is compoſed of 48 parts of potaſs, 20 of acid, and 32 of water. According to Pelletier, of 43 parts of acid, 40 of potaſs, and 17 of water. Bergman under-rated the quantity of acid from not obſerving that the ſalt loſes part of its acid when heated. Even ſolution in hot water produces a ſeparation of ſome acid†.

It is not altered by expoſure to the air.

Heat deprives it of its water and part of its acid, but does not decompoſe it completely. The following ſalts decompoſe it by compound affinity:

Sulphat of lime,
——— barytes,
——— ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Muriat of barytes,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
——— ſoda*,
Nitrat of lime,
Nitrat of barytes,
——— ſoda,
——— ammonia,
——— magneſia,
——— alumina,
Acetite of barytes,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Oxy-muriat of mercury,
Phoſphat of lime||.

When potaſs is ſaturated with carbonic acid it always lets fall a quantity of ſilica. Mr Pelletier has propoſed this ſaturation as the beſt method of purifying potaſs from that earth.

771 Carbonat of ſoda,

2. Carbonat of ſoda. This ſalt may be formed in the ſame manner with carbonat of potaſs.

Its cryſtals are five-ſided priſms, with one of the angles frequently truncated, ſurmounted by dihedral pyramids with rhomboidal faces.

Its taſte is preciſely the ſame with that of carbonat of potaſs.

It is ſoluble in double its weight of cold water.

It is compoſed, according to Bergman, of 16 parts of acid, 20 of alkali, and 64 of water.

It effloreſces when expoſed to the air. Heat is incapable of decompoſing it completely*.

The following ſalts decompoſe it by compound affinity:

Sulphat of ammonia,
——— barytes,
——— lime,
——— magneſia‡,
——— alumina,
Muriat of barytes,
——— ammonia,
——— lime,
——— magneſia,
——— alumina,
Acetite of barytes,
——— ammonia,
——— lime,
——— magneſia,
——— alumina,
Nitrat of ammonia,
——— magneſia,
——— alumina,
——— lead†,
Phoſphat of lime*.

772 Carbonat of ammonia,

3. Carbonat of ammonia. This ſalt forms octahedral cryſtals, having for the moſt part their two oppoſite apexes truncated‡.

Its taſte and ſmell, though much weaker, are the ſame with thoſe of pure ammonia. Like all the alkaline carbonats it converts vegetable blues to green, preciſely as pure alkalies do.

It is ſoluble in rather leſs than twice its weight of cold water. Hot water diſſolves its own weight of it.

According to Bergman it is compoſed of 43 parts of alkali, 45 of acid, and 12 of water.

When expoſed to the air it becomes ſomewhat moiſt.

The ſmalleſt heat is ſufficient to evaporate it.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,
Nitrat of lime,
Muriat of lime,
——— magneſia,
——— alumina,
Acetite of barytes,
——— lime,
——— magneſia,
——— alumina.

773 Carbon of bary

4. Carbonat of barytes. This ſalt has been found native.

Its cryſtals have been obſerved to aſſume four different forms; double ſix-ſided and double four-ſided pyramids, ſix-ſided columns terminated by a pyramid with the ſame number of faces, and ſmall radiated cryſtals ½ an inch in length, and very thin, appearing to be hexagonal priſms, rounded towards the point.

Cold water diſſolves $\frac{1}{4304}$ part, and boiling water $\frac{1}{2304}$ part of this ſalt. Water ſaturated with carbonic acid diſſolves $\frac{1}{830}$th part*.

According to Dr Withering, who firſt diſcovered it native, it is compoſed of 80 parts of barytes and 20 of acid. Bergman informs us, that artificial carbonat is compoſed of 7 parts of acid, 28 of water, and 65 of earth†.

It is not altered by expoſure to the air.

It is decompoſed by the application of a very violent heat¶.

By compound affinity it is decompoſed by the following ſalts:

Sulphat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
——— alumina,
Nitrat of ſoda,
——— lime,
——— ammonia,
——— magneſia,
Nitrat of alumina,
Muriat of lime,
——— ammonia,
——— magneſia,
——— alumina,
Acetite of lime,
——— magneſia,
——— alumina.

774 Carbon of lime

5. Carbonat of lime. This ſubſtance, under the names of marble, chalk, lime-ſtone, &c. exiſts in great abundance in nature, variouſly mixed with other bodies.

When pure, it is of a white colour, and has very little taſte.

It is inſoluble in pure water: but water ſaturated with carbonic acid diſſolves $\frac{1}{1500}$ part of it; from this ſolution it gradually precipitates as the acid leaves it in the form of ſmall rhomboidal cryſtals*.

It is compoſed, according to Bergman, of 34 parts of acid, 11 of water, and 55 of lime.

It ſuffers little or no alteration by being expoſed to the air.

When expoſed to heat, it firſt loſes its water, and afterwards its acid ſeparates as the heat is increaſed: But to ſeparate the acid completely, a very ſtrong heat is required.

The following ſalts decompoſe it by compound affinity:

Sulphat of alumina,
——— copper.

775 Carbon of ſtrontites,

6. Carbonat of ſtrontites. This ſalt, which was firſt examined by Dr Hope, is inſipid, and ſoluble in 1536 parts

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‡ *Bergman*, i. 13.

§ *Pelletier*.

† *Id.*

* *Bergman*.

|| *Id.*

* *Bergman*, i. 18.

‡ *Bergman*.

† *Id.*

* *Id.*

‡ *Bergman*, i. 21.

* *Fourcr Ann. de Chim.* i 64.

† *Bergm* i. 21.

¶ *Dr E*

* *Bergm* i. 21.

Acetites.

hol. It is not ſo eaſily decompoſed by heat as nitrat of jargonia, probably becauſe it does not adhere ſo ſtrongly to water[*].

788 Acetite of ron.

10. Acetite of iron. This ſalt was mentioned by Schrœder and Juncker. It is compoſed of acetous acid and brown oxyd of iron.

Its ſolution forms by gentle evaporation ſmall oblong cryſtals. But the greateſt part of the ſalt aſſumes the form of a gelatinous maſs[‡].

It has a ſweetiſh ſtyptic taſte.

According to Wenzel, 240 parts of acetous acid require for ſaturation $186\frac{1}{2}$ of iron.

Heat decompoſes this ſalt; and it ſeems alſo to be gradually decompoſed by expoſure to the air.

789 Acetite of inc.

11. Acetite of zinc. This ſalt was firſt mentioned by Glauber.

Its cryſtals are rhomboidal, and ſometimes hexagonal plates of a white colour, and the appearance of talk.

It is ſoluble in water. According to Wenzel, 240 parts of acetous acid require for ſaturation $195\frac{5}{6}$ths of zinc.

It is not altered by expoſure to the air. Heat decompoſes it. When thrown upon burning coals, it explodes with a blue flame.

12. Acetite of mangaueſe. This ſalt is not cryſtallizable; and when evaporated to dryneſs, it deliqueſces. Is it not an acetat?

790 Acetite of obalt.

13. Acetite of cobalt. This ſalt is deliqueſcent. Its ſolution is of a fine red colour while cold; but becomes blue by being heated, and it recovers its former colour on cooling. According to Wenzel, 240 parts of acetous acid require for ſaturation $241\frac{5}{7}$ths of cobalt.

791 Acetite of ickel.

14. Acetite of nickel. This ſalt forms rhomboidal cubes of a green colour[||]. They are not deliqueſcent: Their taſte is ſweet[*].

792 Acetite of ead.

15. Acetite of lead. This ſalt is mentioned by Iſaac Hollandus and Raymond Lully. It is compoſed of acetous acid and white oxyd of lead.

It was formerly called *ſugar of lead*, *ſugar of Saturn*, *ſalt of Saturn*, *vinegar of Saturn*, *extract of Saturn*, &c.

Its cryſtals are flat parallelopipeds, terminated by two inclined planes approaching each other.

It has a ſweet and ſomewhat aſtringent taſte.

It is not very ſoluble in water; but acetous acid diſſolves it abundantly.

According to Wenzel, 240 parts of acetous acid require for ſaturation 503 of lead.

When expoſed to the air it becomes yellow, but undergoes no other alteration.

Heat decompoſes it by deſtroying the acid. When diſtilled, the reſiduum takes fire ſpontaneouſly on expoſure to the air. Paper dipped into acetite of lead forms excellent matches, which are not ſubject to go out, and which burn very ſlowly.

The following ſalts decompoſe it by compound affinity:

Muriat of ammonia,
Sulphat of copper,
Phoſphat of ſoda,
Phoſphat of ammonia,
Oxalat of potaſs[||],
Malat of potaſs[†].

793 Acetite of tin.

16. Acetite of tin. This ſalt was firſt deſcribed by Lemery.

Its cryſtals are priſmatic needles in groups[‡]. According to Wenzel 240 parts of acetous acid require for ſaturation $3\frac{5}{11}$ of tin.

794 Acetite of copper.

17. Acetite of copper. This ſalt was known to the ancients, and various ways of preparing it are deſcribed by Pliny[¶]. It was formerly known by the names of *cryſtals of Venus and verdigriſe*.

It is of a deep green colour. Its cryſtals are rhomboids.

It has a diſagreeable coppery taſte.

It is ſoluble in water and in alcohol.

According to Wenzel 240 parts of acetous acid require $16\frac{1}{8}$ of copper for ſaturation.

It effloreſces when expoſed to the air. Heat decompoſes it. It is uſed in painting.

795 Acetite of biſmuth.

18. Acetite of biſmuth. This ſalt ſeems to have been firſt mentioned by Geoffroi. He called it *ſugar of biſmuth*.

It is moſt eaſily procured by mixing together the ſolutions of nitrat of biſmuth and acetite of potaſs. It forms brilliant, talky, ſilvery cryſtals.

It has a ſweetiſh taſte. According to Wenzel, 240 parts of acetous acid require for ſaturation $15\frac{5}{9}$ of biſmuth.

It does not deliqueſce when expoſed to the air. Heat decompoſes it.

796 Acetite of antimony.

19. Acetite of antimony. It yields with difficulty ſmall cryſtals[†]. According to Wenzel, 240 parts of acetous acid require for ſaturation $1\frac{1}{3}$ of antimony.

797 Acetite of arſenic.

20. Acetite of arſenic. This ſalt forms ſmall cryſtals in grains, hardly ſoluble in water[*].

798 Acetite of mercury.

21. Acetite of mercury. This ſalt is mentioned by Schrœder.

Its cryſtals are ſmall thin plates.

It has a diſagreeable taſte, and excites coughing.

It is hardly ſoluble in water. According to Wenzel, 240 parts of acetous acid require for ſaturation $240\frac{3}{7}$ of mercury.

When expoſed to the air it becomes black, owing to the reduction of the oxyd of mercury. Heat decompoſes it.

799 Acetite of ſilver.

22. Acetite of ſilver. This ſalt was perhaps firſt deſcribed by Margraf.

It is beſt formed by dropping acetite of ſoda or potaſs into a ſaturated ſolution of nitrat of ſilver[†].

It forms ſmall oblong cryſtals, eaſily diſſolved in water[‡]. It has a ſharp taſte.

According to Wenzel, 240 parts of acetous acid require for ſaturation $101\frac{4}{9}$ of ſilver.

Heat decompoſes it. It is decompoſed by muriat of magneſia[¶].

800 Acetite of gold.

23. Acetite of gold. This ſalt is mentioned by Schrœder and Juncker.

801 Acetite of uranium.

24. Acetite of uranium. This ſalt was firſt formed by Klaproth.

Its cryſtals are regular four-ſided ſlender priſms, terminated at both ends by regular quadrilateral pyramids: they are tranſparent, and of a beautiful topaz yellow colour.

Heat decompoſes them: and what is ſingular, if they be heated gradually red hot, the oxyd which remains retains nearly the form of the cryſtals[*].

802 Acetats.

The compounds into which the acetic acid enters, are called *acetats*. They are ſo imperfectly known at preſent, that we ſhall not attempt a deſcription of them.

Sect. XII. *Of Oxalats.*

The compounds of which oxalic acid forms a part

Vauque- n, Ann. de him. xxii. 06.

[‡] Wenzel.

Bergman.

Monnet.

[||] Scheele.

[†] Id.

[‡] Morveau.

[¶] Lib. xxxiv. c. 11.

[†] Wenzel.

[*] Bergman.

[†] Maret, ibid.

[‡] Margraf.

[¶] Bergman.

[*] Klaproth on Uranium.

has been long known. It is obtained in a ſtate of impurity at the bottom, and adhering to the ſides of caſks in which wine has fermented. It is called tartar, ſays Paracelſus, becauſe it produces the oil, water, limeſtone, and ſalt, which burn the patient as *Hell* does. According to him, it was the principle of every diſeaſe and every remedy, and all things contain the germ of it.

Margraf and Rouelle firſt demonſtrated that it contained potaſs ready formed: and Scheele firſt obtained tartarous acid from it in a ſtate of purity.

Its cryſtals are very ſmall and irregular. According to Montet, they are priſms, ſomewhat flat, and moſtly with ſix ſides. It has a ſtrong acid taſte. It is ſoluble in about 30 times its weight of boiling water ¶. According to Bergman, it contains 23 parts of alkali and 77 of acid.

It is not altered by expoſure to the air. Heat decompoſes it, and at the ſame time deſtroys the acid. It is capable of forming a great many compounds.

810 Tartrite of potaſs.

2. Tartrite of potaſs. This ſalt may be formed by ſaturating the laſt deſcribed ſalt with potaſs. It was formerly called *ſoluble tartar,* becauſe it is much more ſoluble in water than the acidulous tartrite of potaſs. It cryſtallizes moſt readily when there is a ſmall exceſs of alkali in the ſolution. Its cryſtals are ſmall oblongs.

It has an unpleaſant bitter taſte. It is ſoluble in 4 parts of water, at the temperature of 40°.

3. Tartrite of ſoda. This ſalt has never been accurately examined.

811 Tartrite of potaſs and ſoda.

4. Tartrite of potaſs and ſoda. This triple ſalt, formerly known by the name of ſalt of Seignette, becauſe firſt formed by Mr Seignette apothecary at Rochelle, is made by ſaturating tartar with ſoda.

Its cryſtals are priſms of eight or ten unequal ſides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes, and the baſe on which they ſtand is marked with two diagonal lines, ſo as to divide it into four triangles.

It has a bitter taſte. It is almoſt as ſoluble as tartrite of potaſs.

It effloreſces when expoſed to the air. Heat decompoſes it.

812 Tartrite of ammonia.

4. Tartrite of ammonia. The cryſtals of this ſalt are polygonous priſms, not unlike thoſe of the laſt deſcribed ſalt.

It has a cooling bitter taſte like that of nitre. It is eaſily ſoluble in water. Heat decompoſes it.

5. Acidulous tartrite of ammonia. This ſalt may be formed by pouring tartarous acid into a ſolution of tartrite of ammonia. Like acidulous tartrite of potaſs it is very inſoluble in water.

6. Tartrite of potaſs and ammonia. This triple ſalt may be formed by pouring ammonia into acidulous tartrite of potaſs.

Its cryſtals, according to Macquer, are priſms with four, five, or ſix ſides: according to the Dijon academicians, parallelopipeds, with two alternate ſloping ſides.

It has a cooling taſte. It is ſoluble enough in water. It effloreſces in the air. Heat decompoſes it.

813 Earthy tartrites.

7. Tartrite of barytes. Unknown.

8. Tartrite of lime. This ſalt, firſt formed by Scheele, is a taſteleſs and almoſt inſoluble powder. By heat the acid is decompoſed, and the pure lime remains behind.

9. Tartrite of ſtrontites. This ſalt was firſt formed by Dr Hope. Its cryſtals are ſmall regular triangular tables, having the edges and angles ſharp and well defined. It is inſipid. It diſſolves in 320 parts of boiling water.

It is not altered by expoſure to the air. Heat decompoſes it by deſtroying the acid.*

10. Tartrite of magneſia. This ſalt is inſoluble in water except there be an exceſs of acid preſent. It then affords by evaporation ſmall cryſtals in the form of hexangular truncated priſms†.

It has a more ſaline taſte, and is more fuſible than tartrite of lime‡.

Heat firſt melts and afterwards decompoſes it.

11. Tartrite of alumina. This ſalt does not cryſtallize, but forms by evaporation a clear tranſparent gummy maſs. Its taſte is aſtringent. It is ſoluble in water. It does not deliqueſce in the air.*

12. Tartrite of potaſs and alumina. This triple ſalt is formed by ſaturating tartar with alumina. It bears a very ſtriking reſemblance to the laſt deſcribed ſalt.

814 Metallic tartrites.

13. Tartrite of iron. This is a grey powder. When tartarous acid is poured into a ſolution of ſulphat of iron, ſcaly cryſtals are formed by evaporation. Theſe cryſtals are doubtleſs compoſed of tartarous acid combined with ſulphat of iron. This triple ſalt might be called *tartro-ſulphat of iron.*

14. Tartrite of potaſs and iron. This triple ſalt was formerly called *tartariſed tincture of Mars, chalybeated tartar,* and *tartariſed iron.* It may be formed by boiling two parts of tartar and one of iron filings, previouſly made up into a paſte, in a proper quantity of water. The liquor by evaporation depoſits cryſtals, which form the ſalt wanted.

15. Tartrite of zinc. This ſalt is not eaſily ſoluble in water.

16. Tartrite of potaſs and zinc. This triple ſalt, formed by combining tartar and oxyd of zinc, is very ſoluble in water‡.

17. Tartrite of lead. This ſalt, which is compoſed of tartarous acid and white oxyd of lead, is almoſt inſoluble in water. Nitric acid diſſolves it.

18. Tartrite of potaſs and lead. This ſalt, formed by combining white oxyd of lead with tartar, is very ſoluble in water.*

19. Tartrite of tin. Unknown. The tartrite of potaſs and tin, compoſed of tartar and oxyd of tin, is capable of cryſtallizing.

20. Tartrite of copper. This ſalt is beſt formed by pouring tartarous acid into the ſolutions of muriat or ſulphat of copper; it precipitates in the form of blue cryſtals ¶.

This ſalt forms the beſt kind of the pigment called *Brunſwick green*‡.

21. Tartrite of potaſs and copper. This triple ſalt is alſo in the form of blue cryſtals.

22. Tartrite of biſmuth. Small cryſtalline grains‖.

23. Tartrite of antimony. This ſalt has never been examined with attention.

24. Tartrite of potaſs and antimony, or tartar emetic. To this ſalt, which is perhaps the moſt powerful emetic known, a great deal of attention has been paid, and a vaſt number of methods have been tried to prepare it. Theſe methods have been already deſcribed in the Encyclopædia. It appears from the experiments of Mr Bindheim, that if this ſalt be carefully prepared, the difference that reſults from the uſe of different oxyds is not ſo great as might have been expected†.

It was firſt made known by Adrian in 1631. It is a

¶ *Wenzel.*

* *Hope, Edin. Tranſ.* iv. 15.

† *Bergman,* ii. 288.

‡ *Von Packen de Sale eſſent. acid. Tartar.*

* *Von Packen.*

‡ *Elemens de Chim. Dijon.*

* *Wenzel.*

¶ *Bergman.*

‡ *Leonhardi.*

‖ *Bergman.*

† *Ann. de Chim.* xiii. 218.

triple ſalt, compoſed of tartar and white oxyd of antimony.

It is of a white colour and tranſparent. Its cryſtals are trihedral pyramids.

It diſſolves in 60 parts of cold water, and in a ſmaller proportion of hot water. It is decompoſed by lime and alkalies, iron, &c. Care ought therefore to be taken to uſe only diſtilled water when it is adminiſtered as a medicine.

25. Tartrite of arſenic. This ſalt forms priſmatic cryſtals very like thoſe of oxalt of arſenic ¶.

26. Tartrite of mercury. A yellow powder.

27. Tartrite of potaſs and mercury. This triple ſalt cryſtallizes†.

Sect. XIV. *Of Citrats.*

The compounds into which the citric acid enters have been denominated *citrats.*

Theſe ſalts are at preſent very imperfectly known. Mr Dizé has promiſed ſoon to ſupply this defect.*

815 Alkaline citrats.

1. Citrat of potaſs. This ſalt does not cryſtallize. It has a cooling ſaline taſte, and deliqueſces when expoſed to the air.

2. Citrat of ſoda. This ſalt does not deliqueſce. It has a mild, pleaſant, cooling taſte ¶. According to Scheele it does not cryſtallize.

3. Citrat of ammonia. This ſalt cryſtallizes in thin needles. It has a cooling and moderately ſaline taſte‡. The ammonia is ſeparated by the application of heat.*

816 Earthy citrats.

4. Citrat of barytes. This ſalt is ſcarcely ſoluble in water. It aſſumes the form of a white powder†. It is ſoluble in citric acid.

5. Citrat of lime. This is a white powder, ſcarcely ſoluble in water‖.

6. Citrat of magneſia. Does not cryſtallize. It forms a gummy ſaline maſs very ſoluble in water‡.

7. Citrat of alumina. This ſalt is ſcarcely ſoluble in water.

817 Metallic citrats.

8. Citrat of iron. A ſolution of a brown colour.

9. Citrat of copper. A green gummy maſs.

10. Citrat of mercury. This ſalt may be formed by pouring citric acid into nitrat or acetite of mercury. It is a flaky ſalt, of a brick-duſt colour, more or leſs red†.

Sect. XV. *Of Malats.*

The compounds into which the malic acid enters are called *malats.* This claſs of ſalts was firſt diſcovered by Scheele. They are no better known than the citrats.

818 Malats.

1. Malat of potaſs.
2. Malat of ſoda.
3. Malat of ammonia.
These ſalts are deliqueſcent‡.

4. Malat of lime. Small irregular cryſtals. They require a large quantity of boiling water for their ſolution. With exceſs of acid they are readily ſoluble in cold water§. They are inſoluble in alcohol‖.

5. Malat of barytes. The properties of this ſalt reſemble pretty much thoſe of malat of lime¶.

6. Malat of magneſia. Deliqueſcent‡.

7. Malat of iron. A brown ſolution, not cryſtallizable†.

8. Malat of zinc. This ſalt forms beautiful cryſtals¶.

Sect. XVI. *Of Lactats.*

819 Lactats.

The neutral ſalts formed by the combination of the lactic acid with various baſes are called *lactats.* They were firſt diſcovered by Scheele.

1. Lactat of potaſs. A deliqueſcent ſalt, ſoluble in alcohol§.

2. Lactat of ſoda. This ſalt does not cryſtallize. It is ſoluble in alcohol†.

3. Lactat of ammonia. Cryſtals which deliqueſce. Heat ſeparates a great part of the ammonia before deſtroying the acid.

4. Lactat of barytes.
5. Lactat of lime.
6. Lactat of alumina.
Theſe ſalts deliqueſce§. The lactat of lime is ſoluble in alcohol‡.

7. Lactat of magneſia. Small deliqueſcent cryſtals‖.

8. Lactat of iron. A brown ſolution.

9. Lactat of zinc. Cryſtals.*

Theſe ſalts have a very ſtrong reſemblance to malats. The only difference which Scheele obſerved was, that the malat of lime was inſoluble in alcohol, while alcohol diſſolved lactat of lime.

Sect. XVII. *Of Saccholats.*

820 Sacchola[ts.]

The compounds into which the ſaccholactic acid enters are called *ſaccholats.* They alſo were firſt diſcovered by Scheele.

1. Saccholat of potaſs. Small cryſtals, ſoluble in eight times their weight of boiling water.*

2. Saccholat of ſoda. The ſame; ſoluble in five times their weight of boiling water§.

3. Saccholat of ammonia. A ſalt which has a ſouriſh taſte. Heat ſeparates the ammonia†.

4. Saccholat of barytes.
5. Saccholat of lime.
6. Saccholat of magneſia.
7. Saccholat of alumina.
Theſe ſalts are inſoluble in water¶.

Sect. XVIII. *Of Gallats.*

821 Gallats.

The compounds into which the gallic acid enters are denominated *gallats.* They were firſt attended to by the Dijon academicians and by Scheele.

1. Gallat of potaſs.
2. Gallat of ſoda.
3. Gallat of ammonia.
We only know that theſe compoſitions are poſſible, and that their properties are different from thoſe of all other ſalts.

4. Gallat of barytes.
5. Gallat of lime.
Theſe ſalts are ſoluble in water, eſpecially when there is exceſs of acid.

6. Gallat of magneſia. This ſalt is a yellow powder, ſoluble in water and in alcohol‖.

7. Gallat of alumina. This ſalt, according to Bartholdi, exiſts ready formed in nut galls. It is very ſoluble in water.

8. Gallat of iron. This ſalt, which Mr Prouſt has diſcovered to be formed of gallic acid and brown oxyd of iron, is of a black colour, and does not ſeem capable of cryſtallizing. It is ſoluble in the three mineral acids, and by that means is deprived of its black colour. It is to this ſalt that ink partly owes its black colour. Gallat of iron is decompoſed by alkalies.

We ſhall not attempt any farther account of this claſs of ſalts. Scarcely any addition has yet been made to the zoats. the experiments of Scheele which have been given already in the article Chemistry, *Encycl.*

¶ Bergman, ii. 295.

† Monnet.

* Jour. de Phyſ. 1794. Supplement.

¶ Dr Donald Monro, Phil. Tranſ. 57.

‡ Dobſon.

* Scheele.

† Id.

‖ Id.

‡ Id.

† Dizé.

‡ Scheele.

§ Id.

‖ Id.

¶ Id.

‡ Id.

† Id.

¶ Id.

§ Scheele Milk.

† Ibid.

§ Ibid.

‡ Ibid.

‖ Ibid.

* Ibid.

* Scheele Sugar of Milk.

§ Ibid.

† Ibid.

¶ Ibid.

‖ Barthol Ann. de Chim. xii 305.

Sect. XIX. *Of Benzoats.*

822 aline zoats. The compounds into which the benzoic acid enters have been called *benzoats*.

1. Benzoat of potaſs. This ſalt forms pointed feathery cryſtals. It has a ſaline ſharp taſte. It is very ſoluble in water. It deliqueſces when expoſed to the air¶.

2. Benzoat of ſoda. The cryſtals of this ſalt are larger, but its taſte is the ſame with that of benzoat of potaſs. It is alſo very ſoluble in water. It effloreſces in the air†.

3. Benzoat of ammonia. This ſalt cryſtallizes with difficulty. Its cryſtals are feather-ſhaped. It deliqueſces‡.

823 thy zoats. 4. Benzoat of lime. This ſalt forms white, ſhining, pointed cryſtals, of a ſweetiſh taſte, and not eaſily ſoluble in water§.

5. Benzoat of magneſia. Feather-ſhaped cryſtals, of a ſharp bitter taſte, and eaſily ſoluble in water||.

6. Benzoat of alumina. An aſtringent ſalt.

824 talline zoats. 7. Benzoat of iron. This ſalt forms yellow cryſtals. It has a ſweet taſte. It is ſoluble in water and alcohol. It effloreſces in the air. Heat diſengages the acid†.

8. Benzoat of zinc. This ſalt forms arboreſcent cryſtals. It is ſoluble in water and alcohol. When expoſed to the air it is diſſipated. Heat decompoſes it‡.

9. Benzoat of manganeſe. This ſalt, which is formed of benzoic acid and white oxyd of manganeſe, cryſtallizes in ſmall ſcales. It diſſolves readily in water, with difficulty in alcohol. It is not altered by expoſure to the air¶.

10. Benzoat of cobalt. Flat cryſtals‡.

11. Benzoat of lead. Very white cryſtals, ſoluble in water and alcohol. They are not altered by expoſure to the air. Heat diſengages the acid||.

12. Benzoat of tin. This ſalt may be formed by pouring benzoat of potaſs into a ſolution of tin in the nitro-muriatic acid. The benzoat of tin is precipitated. It is ſoluble in hot water, but inſoluble in alcohol. Heat decompoſes it§.

13. Benzoat of copper. Small cryſtals of a deep green colour. They are with difficulty ſoluble in water, and not at all in alcohol†.

14. Benzoat of biſmuth. This ſalt forms white needle-ſhaped cryſtals. They are ſoluble in water and in a very ſmall proportion in alcohol. They are not altered by expoſure to the air. Heat decompoſes them¶.

15. Benzoat of antimony. Cryſtals which effloreſce in the air, and are decompoſed by heat||.

16. Benzoat of arſenic. Small feather-ſhaped cryſtals. It is ſoluble in hot water, but cryſtallizes in the cooling. A moderate heat ſublimes it; a ſtrong heat decompoſes it. Sulphur decompoſes it. It is not decompoſed by alkalies‡.

17. Benzoat of mercury. A white powder. It is inſoluble in water, but diſſolves in a ſmall quantity in alcohol. It is not altered by expoſure to the air. A ſmall heat ſublimes it; a greater decompoſes it. It is decompoſed by ſulphur†.

18. Benzoat of ſilver. This ſalt is ſoluble in water and alſo in a very ſmall proportion in alcohol. It is not altered by expoſure to the air, but the rays of the ſun render it brown. Heat diſengages its acid||.

19. Benzoat of gold. Small irregular cryſtals, not eaſily ſoluble in water; inſoluble in alcohol. It is not altered by expoſure to the air. Heat decompoſes it¶.

20. Benzoat of platinum. This ſalt forms ſmall browniſh cryſtals, with difficulty ſoluble in water; not ſoluble in alcohol. When expoſed to heat, it is decompoſed, and there remains behind a brown powder§.

Sect. XX. *Of Succinats.*

The neutral ſalts, formed by the combination of the ſuccinic acid with various baſes, have been called *ſuccinats*.

We ſhall not deſcribe theſe ſalts, as we could not add much to the account given in the Appendix to the article Chemistry in the Encyclopædia. That account was taken from Mr Keir's Chemical Dictionary, and that gentleman borrowed it from Leonhardi.

Sect. XXI. *Of Camphorats.*

The neutral ſalts into the compoſition of which camphoric acid enters, have been denominated *camphorats*. The only chemiſt who has hitherto examined them is Bouillon la Grange: his experiments have been publiſhed in the 27th volume of the *Annales de Chimie*.

825 Camphorat of potaſs. 1. Camphorat of potaſs. To prepare this ſalt carbonat of potaſs is to be diſſolved in water, and the ſolution ſaturated with camphoric acid. When the efferveſcence is over, the liquor is to be evaporated by a gentle heat to the proper conſiſtence, and cryſtals of camphorat of potaſs will be depoſited when the liquor cools.

Camphorat of potaſs is white and tranſparent; its cryſtals are regular hexagons. Its taſte is bitteriſh and ſlightly aromatic.

Water at the temperature of 60° diſſolves $\frac{1}{100}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{4}$th part of its weight.

It is ſoluble in alcohol, and the ſolution burns with a deep blue flame.

When expoſed to moiſt air, it loſes a little of its tranſparency, but in dry air it ſuffers no change.

When expoſed to heat it melts, ſwells, and the acid is volatilized in a thick ſmoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potaſs remains behind in a ſtate of purity.

By compound affinity this ſalt is decompoſed by

Nitrat of barytes,
All the ſalts whoſe baſe is lime,
Nitrat of ſilver,
Sulphat of iron,
Muriat of tin,
——— lead*.

826 Camphorat of ſoda. 2. Camphorat of ſoda. This ſalt may be formed preciſely in the ſame manner with the camphorat of potaſs.

It is white and tranſparent; its taſte is ſomewhat bitter; its cryſtals are irregular.

Water at the temperature of 60° diſſolves leſs than $\frac{1}{200}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{8}$th of its weight.

It is alſo ſoluble in alcohol.

When expoſed to the air it loſes its tranſparency, and effloreſces.

¶ eir's ionary.

† bid.

‡ bid.

§ bid.

|| bid.

† romſdorf, . de n. xi. 3.

‡ . ibid.

¶ . ibid.

‡ . ibid.

|| . ibid.

§ . ibid.

† d. ibid.

¶ d. ibid.

|| d. ibid.

‡ d. ibid.

† d. ibid.

|| Id. ibid.

¶ Id. ibid.

§ Id. ibid.

* Bouillon La Grange, Ann. de Chim. xxvii. 24.

Camphorats.

effloreſces ſlightly, but is never completely reduced to powder.

Heat produces the ſame effect upon it as on camphorat of potaſs: the acid burns with a blue flame, which becomes reddiſh towards the end.

By compound affinity it is decompoſed by

Nitrat of lime,
——— ſilver,
Muriat of magneſia,
——— barytes,
——— alumina,
Muriat of lime,
——— iron,
Sulphat of alumina,
——— iron; and many other ſalts with metallic baſes*.

827
Camphorat of ammonia.

3. Camphorat of ammonia. This ſalt may be prepared by diſſolving carbonat of ammonia in hot water, and adding camphoric acid ſlowly till the alkali is ſaturated. It muſt then be evaporated with a very moderate heat, to prevent the diſengaging of ammonia.

It is very difficult to obtain this ſalt in regular cryſtals. When evaporated to dryneſs, there is obtained a ſolid opaque maſs of a ſharp and bitteriſh taſte.

Water at the temperature of about 60° diſſolves nearly $\frac{1}{100}$th part of its weight of this ſalt; boiling water diſſolves $\frac{1}{3}$d of its weight: But this and the two ſalts above deſcribed are a good deal more ſoluble when there is exceſs of baſe.

It is entirely ſoluble in alcohol.

When expoſed to the air it attracts moiſture, but not in ſufficient quantity to enable it to aſſume a liquid form.

When expoſed to heat it ſwells, melts and is converted into vapour; before the blow-pipe it burns with a blue and red flame, and is entirely volatilized.

Moſt of the calcareous ſalts form triple ſalts with camphorat of ammonia.

It decompoſes in part all the aluminous ſalts except the ſulphat of alumina†.

828
Camphorat of barytes.

4. Camphorat of barytes. In order to prepare this ſalt, barytes is to be diſſolved in water, and camphoric acid added to the ſolution; the mixture is then to be boiled, and afterwards filtered and evaporated to dryneſs.

Camphorat of barytes does not cryſtallize; when the evaporation is conducted ſlowly, the ſalt is depoſited in thin plates one above another, which appear tranſparent while immerſed in the liquor, but become opaque whenever they come into contact with the air.

It has very little taſte, though it leaves at laſt upon the tongue a ſlight impreſſion of acidity mixed with bitterneſs.

Water diſſolves only a very ſmall quantity of this ſalt: boiling water being capable of taking up only $\frac{1}{600}$th part of it.

It is not altered by expoſure to the air.

When expoſed to heat it melts eaſily, and the acid is volatilized. When the heat is conſiderable, the acid burns with a lively blue flame, which becomes red and at laſt white.

It is decompoſed by

Nitrat of potaſs, ſoda, lime, ammonia, and magneſia.
Muriat of lime, potaſs, alumina, and magneſia.
All the ſulphats.
Carbonat of potaſs and ſoda.
Phoſphat of potaſs, ſoda, and ammonia*.

829
Camphorat of lime.

5. Camphorat of lime. This ſalt may be prepared by dropping into lime-water cryſtallized camphoric acid. The mixture is then to be made boiling hot, paſſed through a filter, and evaporated to about $\frac{3}{4}$ths of its volume. On cooling camphorat of lime is depoſited.

It has no regular ſhape; but if the evaporation has been properly conducted, it is in plates lying one above another. It is of a white colour, and has a taſte ſlightly bitter.

Water at the temperature of 60° diſſolves very little of this ſalt; boiling water is capable of diſſolving about $\frac{1}{200}$th part of its weight of it. It is inſoluble in alcohol.

It is compoſed of 43 parts of lime, 50 of acid, and 7 of water.

When expoſed to the air it dries and falls into powder.

When expoſed to a moderate heat it melts and ſwells up: when placed on burning coals, or when heated in cloſe veſſels, the acid is decompoſed and volatilized, and the lime remains pure.

When ſulphuric acid is poured into a ſolution of this ſalt, it produces an inſoluble precipitate; nitric and muriatic acids precipitate the camphoric acid.

It is decompoſed by compound affinity by

Carbonat of potaſs,
Nitrat of barytes,
Muriat of alumina,
Sulphat of alumina,
Phoſphat of ſoda*.

6. Camphorat of magneſia. This ſalt may be prepared by pouring water on carbonat of magneſia, and then adding cryſtallized camphoric acid: heat is then applied, the ſolution is filtrated, and evaporated to dryneſs. The ſalt obtained is diſſolved in hot water, paſſed through a filter, and evaporated by means of a moderate heat till a pellicle forms on the ſurface of the ſolution. On cooling the ſalt is depoſited in thin plates. The ſecond ſolution is to remove any exceſs of magneſia that may happen to be preſent.

This ſalt does not cryſtallize. It is white, opaque, and has a bitter taſte.

It is ſcarcely more ſoluble in water than camphorat of lime.

Alcohol has no action on it while cold, but when hot it diſſolves the acid and leaves the magneſia; and the acid precipitates again as the alcohol cools.

When expoſed to the air it dries and becomes covered with a little powder; but this effect is produced ſlowly, and only in a warm place.

When this ſalt is placed on burning coals, the acid is volatilized, and the magneſia remains pure. Before the blow-pipe it burns like the other camphorats with a blue flame.

The nitrats, muriats, and ſulphats, do not completely decompoſe this ſalt, if we except the nitrat of lime and muriat of alumina*.

7. Camphorat of alumina. To prepare this ſalt, alumina, precipitated by means of ammonia, and well waſhed, is to be mixed with water, and cryſtals of camphoric acid added. The mixture is then to be heated, filtered, and concentrated by evaporation.

This ſalt is a white powder, of an acid bitteriſh taſte, leaving to the tongue, like moſt of the aluminous ſalts, a ſenſation of aſtringency.

Water at the temperature of 60° diſſolves about $\frac{1}{200}$th part of its weight of this ſalt. Boiling water diſſolves

it

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* *Bouillon La Grange, Ann. de Chim.* xxvii. 26.

† *Ibid.*

* *Bouillon La Grange, ibid.* p. 28.

is inſoluble in water, and ſcarcely ſoluble in acids. It is compoſed, according to the moſt accurate experiments hitherto made, of equal parts of oxyd of iron and pruſſic acid. It is not affected by expoſure to the air. Heat decompoſes it by deſtroying the acid, and the oxyd of iron remains behind.

The Pruſſian blue of commerce, beſides other impurities, contains mixed with it a great quantity of alumina. Its uſe as a pigment, and the attempts which have been made to introduce it as a dye, are well known.

Pruſſiat of iron may alſo exiſt in another ſtate: It may have a ſuperabundance of oxyd; its colour is then more or leſs yellow. To this ſtate it may be reduced by digeſting it with alkalies or any of the alkaline earths. Theſe ſubſtances deprive it of part of its acid, but not of the whole.

842 This yellow pruſſiat is ſoluble in acids.

Affinities of the pruſſic acid explained.

Were we to attempt an explanation of this, and the other phenomena which the pruſſic acid diſplays in its combinations, we would conjecture, that this yellow pruſſiat is the ſubſtance formed by the direct combination of brown oxyd of iron and pruſſic acid, and that the blue pruſſiat is formed of the yellow pruſſiat combined as an integrant with pruſſic acid: That the affinity between the pruſſic acid and oxyd of iron is much ſtronger than that between yellow pruſſiat of iron and pruſſic acid: that therefore alkalies and earths have a ſtronger affinity for pruſſic acid than the yellow pruſſiat has, but a much weaker affinity than oxyd of iron, and perhaps every other oxyd;—hence the apparent ſuperiority of alkalies and earths in ſome caſes, while in others they appear very inferior. We would ſuppoſe, then, that the pruſſic acid has a much ſtronger affinity for oxyd of iron, and perhaps for all other oxyds, than for other bodies; that the pruſſiats, thus formed, are capable of combining with pruſſic acid; but that their affinity for it is much leſs than that of the alkalies and earths. This conjecture is ſupported by all the phenomena at preſent known; it would remove all the apparent anomalies which the combinations of this ſingular acid preſent, and reduce the whole of them under the known laws of affinity.

843 Properties of Pruſſian alkali,

8. Pruſſiat of potaſs and iron, commonly called *Pruſſian alkali*, or *Pruſſian teſt*. This ſubſtance is a triple ſalt, compoſed of pruſſic acid, potaſs, and oxyd of iron combined together. To chemiſts and mineralogiſts it is one of the moſt important inſtruments ever invented; as, when properly prepared, it is capable of indicating whether any metallic ſubſtance (platinum excepted) be preſent in any ſolution whatever, and even of pointing out the particular metal, and of aſcertaining its quantity: This it does by means of a compound affinity, which, after what has been ſaid above, may be eaſily underſtood. The Pruſſian alkali may be conceived to be a combination of two ſubſtances, pruſſiat of potaſs and blue pruſſiat of iron. Now every metallic oxyd has a ſtronger affinity for pruſſic acid than potaſs has (and, in fact, ſeems to have a ſtronger affinity for it than for any other ſubſtance). If, therefore, there happen to be any oxyd in the ſolution, it immediately ſeizes the pruſſic acid with which the potaſs is combined, and by that means decompoſes the triple ſalt. A pruſſiat of the particular metal is formed, and, as moſt pruſſiats of metals are inſoluble, it is precipitated; and it indicates by its colour the particular metal, and by its weight the quantity of metal that happens to be preſent. At the ſame time, the blue pruſſiat of iron is alſo precipitated, and its weight muſt be deducted from the quantity of the precipitate.

In order to be certain of the accuracy of theſe reſults, it is neceſſary to have a Pruſſian alkali perfectly pure, and to be certain before hand of the quantity, or rather of the proportions of its ingredients. To obtain a teſt of this kind has been the object of chemiſts ever ſince the diſcoveries of Macquer pointed out its importance. It is to the uſe of impure teſts that a great part of the contradictory reſults of mineralogical analyſes by different chemiſts is to be aſcribed.

There are two ‡ ways in which this teſt may be rendered impure, beſides the introduction of foreign ingredients, which we do not mention, becauſe it is obvious that it muſt be guarded againſt. 1. There may be a ſuperabundance of alkali preſent, or, which is the ſame thing, there may be mixed with the Pruſſian teſt a quantity of pure alkali; or, 2. There may be contained in it a quantity of yellow pruſſiat of iron, for which pruſſiat of potaſs has alſo a conſiderable affinity.

8 Liabl impu

If the Pruſſian teſt contain a ſuperabundance of alkali, two inconveniences follow. This ſuperabundant quantity will precipitate thoſe earthy ſalts which are liable to contain an exceſs of acid, and which are only ſoluble by that exceſs: Hence alumina and barytes will be precipitated. It is to the uſe of impure teſts of this kind that we owe the opinion, that barytes and alumina are precipitated by the Pruſſian alkali, and the conſequent theories of the metallic nature of theſe earths. This miſtake was firſt corrected, we believe, by Mr Klaproth.

Another inconvenience ariſing from the ſuperabundance of alkali in the Pruſſian teſt is, that it gradually decompoſes the blue pruſſiat which the teſt contains, and converts it into yellow pruſſiat. In what manner it does this will be underſtood, after what has been ſaid, without any explanation.

On the other hand, when the Pruſſian alkali contains a quantity of yellow pruſſiat of iron, as great inconveniences follow. This yellow pruſſiat has an affinity for pruſſic acid, which, though inferior to that of the potaſs, is ſtill conſiderable; and, on the other hand, the potaſs has a ſtronger affinity for every other acid than for the pruſſic. When, therefore, the teſt is expoſed to the air, the carbonic acid, which the atmoſphere always contains, aſſiſted by the affinity between the yellow pruſſiat and the pruſſic acid, decompoſes the pruſſiat of potaſs in the teſt; and the yellow pruſſiat is precipitated in the form of Pruſſian blue: And every other acid produces the ſame effect. A teſt of this kind, therefore, would indicate the preſence of iron in every mixture which contains an acid (for a precipitation of Pruſſian blue would appear); and could not, therefore, be truſted to with any confidence.

Klap meth form

We will not attempt to deſcribe the various methods which different chemiſts have adopted of preparing this teſt; but ſhall ſatisfy ourſelves with deſcribing the method of Klaproth, which anſwers the purpoſe completely. This we ſhall do nearly in the words of Mr Kirwan.

Prepare a pure potaſs, by gradually projecting into a large crucible heated to whiteneſs a mixture of equal parts of purified nitre and cryſtals of tartar; when the whole is

‡ See wan i. 48

is injected, let it be kept at a white heat for half an hour, to burn off the coal.

Detach the alkali thus obtained from the crucible, reduce it to powder, ſpread it on a muffle, and expoſe it to a white heat for half an hour.

Diſſolve it in ſix times its weight of water, and filter the ſolution while warm.

Pour this ſolution into a glaſs receiver placed in a ſand furnace, heated to 170° or 180°, and then gradually add the beſt Pruſſian blue in powder, injecting new portions according as the former becomes grey, and ſupplying water as faſt as it evaporates; continue until the added portions are no longer diſcoloured, then increaſe the heat to 212° for half an hour.

Filter the ley thus obtained, and ſaturate it with ſulphuric acid moderately diluted; a precipitate will appear; when this ceaſes, filter off the whole, and waſh the precipitate.

Evaporate the filtered liquor to about one quarter, and ſet it by to cryſtallize: after a few days, yellowiſh cryſtals of a cubic or quadrangular form will be found mixed with ſome ſulphat of potaſs and oxyd of iron; pick out the yellowiſh cryſtals, lay them on blotting paper, and rediſſolve them in four times their weight of cold water, to exclude the ſulphat of potaſs.

7. Eſſay a few drops of this ſolution with barytic water, to ſee whether it contains any ſulphuric acid, and add ſome barytic water to the remainder if neceſſary: filter off the ſolution from the ſulphat of barytes, which will have precipitated, and ſet it by to cryſtallize for a few days; that the barytes, if any ſhould remain, may be precipitated. If the cryſtals now obtained be of a pale yellow colour, and diſcover no bluiſh ſtreaks when ſprinkled over with muriatic acid, they are fit for uſe; but if they ſtill diſcover bluiſh or green ſtreaks, the ſolutions and cryſtallizations muſt be repeated.

Theſe cryſtals muſt be kept in a well ſtopped bottle, which to preſerve them from the air ſhould be filled with alcohol, as they are inſoluble in it.

Before they are uſed, the quantity of iron they contain ſhould be aſcertained, by heating 100 grains to redneſs for half an hour in an *open* crucible: the pruſſic acid will be conſumed, and the iron will remain in the ſtate of a reddiſh brown magnetic oxyd, which ſhould be weighed and noted: This oxyd is half the weight of the Pruſſian blue afforded by the Pruſſian alkali; its weight muſt therefore be ſubtracted from that of metallic precipitates formed by this teſt. Hence the weight of the cryſtals in a given quantity of the ſolution, ſhould be noted, that the quantity employed in precipitation may be known. Care muſt be taken to continue the calcination till the oxyd of iron becomes brown; for while it is black, it weighs conſiderably more than it ſhould‡.

9. Pruſſiat of ſoda and iron. The only diſcernible difference between this ſalt and the laſt is, that it cryſtallizes differently||.

846 Pruſſiat of mmonia nd iron.

10. Pruſſiat of ammonia and iron. This triple ſalt has alſo been employed as a teſt; but it is not ſo eaſy to obtain it in a ſtate of purity as the other two. It was diſcovered by Macquer, and firſt recommended by Meyer.

It forms flat hexangular cryſtals, ſoluble in water, and deliqueſces in the air. Heat decompoſes it like the other Pruſſiats*.

We ſhall not give any deſcription of the triple ſalts formed by digeſting the alkaline earths on pruſſiat of iron; they are ſufficiently known, and are not of any uſe except as teſts; and in that reſpect they are inferior to that above deſcribed. They are all ſoluble in water, and are moſt of them capable of cryſtallizing.

847 Pruſſiat of mercury.

11. Pruſſiat of mercury. This ſalt, which was firſt formed by Scheele, is compoſed of the pruſſic acid combined with the red oxyd of mercury. It may be formed by boiling the red oxyd of mercury with Pruſſian blue. It cryſtallizes in tetrahedral priſms, terminated by quadrangular pyramids, the ſides of which correſpond with the angles of the priſm.

This ſalt is capable of combining with ſulphuric and muriatic acids, and forming triple ſalts, which have not yet been examined§.

SECT. XXIV. *Of Formats.*

THE compounds into which the formic acid enters are called *formats*. We ſhall not deſcribe them, as little has been added to the account already given in the Appendix to the article CHEMISTRY in the Encyclopædia.

SECT. XXV. *Of Sebats.*

THE compounds into which the ſebacic acid enters are called *ſebats*. For our knowledge of this claſs of ſalts we are chiefly indebted to the celebrated Crell, who publiſhed a diſſertation on the ſebacic acid and its combinations in the Philoſophical Tranſactions for 1780 and 1782.

848 Alkaline ſebats.

1. Sebat of potaſs. This ſalt is of a white colour. Its cryſtals are quadrangular pyramids, of which two oppoſite ſides are narrower than the others. It has a ſharp ſaline taſte like muriat of ammonia, but milder. It is ſoluble in water, inſoluble in alcohol, and does not deliqueſce when expoſed to the air. Heat decompoſes it.

2. Sebat of ſoda. This ſalt is white. Its cryſtals are pyramids, with three or four ſides: a very moderate heat melts them.

3. Sebat of ammonia. This ſalt in taſte and ſolubility reſembles muriat of ammonia, but it differs from it in not being capable of ſubliming iron.

849 Earthy ſebats.

4. Sebat of lime. The cryſtals of this ſalt are hexagons, terminated by a plane ſurface: they have a ſharp acrid taſte: are very ſoluble in water, but not in alcohol: they do not deliqueſce.

5. Sebat of magneſia. A gummy, ſaline, uncryſtallizable maſs.

6. Sebat of alumina. A gummy, ſaline maſs, which does not cryſtallize, and has an auſtere aſtringent taſte.

850 Metallic ſebats.

7. Sebat of iron. Needle-ſhaped cryſtals which deliqueſce.

8. Sebat of lead. Needle-ſhaped cryſtals, very ſoluble in water.

9. Sebat of tin. A white deliqueſcent ſalt.

10. Sebat of copper. This ſalt is capable of cryſtallizing, but is very deliqueſcent.

11. Sebat of antimony. A cryſtallizable ſalt, which does not deliqueſce.

12. Sebat of arſenic. Small cryſtals.

13. Sebat of mercury. A white powder, very difficultly ſoluble in water.

14. Sebat of gold. Yellow cryſtals.

15. Sebat of platinum. Browniſh yellow cryſtals.

The bombats or compounds which the bombic acid forms are ſtill unknown.

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‡ Kirwan's Mineral. 494.

|| Berthollet.

* Woulfe, Journ. de Phyſ. xxxiv. 101.

§ Berthollet.

would be completely decompoſed by water, and their ſulphur precipitated; for water has a ſtronger affinity for the alkalies than ſulphur has. This Berthollet proved by the following experiment: To a ſolution of ſulphuret of potaſs in water (that is, to hydrogenous ſulphuret of potaſs) a quantity of oxy-muriatic acid ſuperſaturated with potaſs was added, and the ſulphur was immediately precipitated. In this experiment the ſulphurated hydrogen was deſtroyed by the oxygen of the oxy-muriatic acid; and the precipitation of the ſulphur ſhews that its affinity for potaſs was not ſufficient to keep it diſſolved, or, which is the ſame thing, that its affinity for potaſs was inferior to that of water.

861 droge- us ſul- uret of rcury.

The ſubſtance which we deſcribed in Part I, chap. iii. ſect. 4. of this article, under the name of *Black Sulphuret of Mercury*, is a hydrogenous ſulphuret of mercury, and therefore differs from the red ſulphuret of mercury or cinnabar, by containing a quantity of ſulphurated hydrogen. Potaſs has a ſtronger affinity for this laſt ſubſtance than the ſulphuret; potaſs therefore, by the aſſiſtance of heat, deprives the black or hydrogenous ſulphuret of its ſulphurated hydrogen, and reduces it to the ſtate of red ſulphuret. This explains the method of forming cinnabar deſcribed in the ſection above referred to, and points out a much eaſier proceſs for obtaining that uſeful pigment.

862 ethod of ming droſul- urets.

We ſhall now proceed to the method of forming the hydroſulphurets. Berthollet obtained ſulphurated hydrogen gas from ſulphuret of iron in the uſual manner, by means of ſulphuric acid. It was made to paſs thro' a veſſel filled with water before it entered that in which the combination was to take place. By this method a ſolution of potaſs was impregnated with ſulphurated hydrogen; and in order to be certain of ſaturating the alkali completely, the gas was added in exceſs, and the exceſs was afterwards driven off by means of heat. By this method hydroſulphurets of potaſs, ſoda, and ammonia, may be formed.

In order to form hydroſulphuret of lime, that earth was mixed with diſtilled water, and ſulphurated hydrogen gas paſſed into this mixture till a ſufficient quantity of hydroſulphuret was judged to be formed; the liquid, which contained it in ſolution, was poured off the undiſſolved lime, and ſaturated to exceſs with ſulphurated hydrogen, and this exceſs was afterwards driven off by means of heat.

Hydroſulphuret of magneſia may be formed by diſſolving magneſia in water impregnated with ſulphurated hydrogen gas.

If a ſolution of ſulphuret of barytes in water, or, more properly, if hydrogenous ſulphuret of barytes be evaporated, a great number of confuſed cryſtals are formed; if theſe be ſeparated quickly by filtration, and placed upon blotting paper to dry, a white cryſtalline ſubſtance is obtained, which is hydroſulphuret of barytes.

863 ffinities f ſulphu- ated hy- rogen.

The affinities of the alkalies and earths for ſulphurated hydrogen appear from the experiments of Berthollet to be as follows:

Barytes,
Potaſs,
Soda,
Lime,
Ammonia,
Magneſia,
Jargonia.

Almoſt all the metallic oxyds have a ſtronger affinity for ſulphurated hydrogen than the earths have.

864 Properties of hydroſulphurets.

When the hydroſulphurets are prepared with the neceſſary precautions to prevent the contact of atmoſpherical air, they are colourleſs, but the action of the air renders them yellow.

If they be decompoſed while they are colourleſs, by pouring upon them ſulphuric acid, muriatic acid, or any other acid which does not act upon hydrogen, the ſulphurated hydrogen gas exhales without the depoſition of a ſingle particle of ſulphur; but if the hydroſulphuret has become yellow, ſome ſulphur is always depoſited during its decompoſition, and the quantity of ſulphur is proportional to the deepneſs of the colour.

The yellow colour, therefore, which hydroſulphurets acquire by expoſure to the atmoſphere is owing to a commencement of decompoſition. Part of the hydrogen of the ſulphurated hydrogen abandons the ſulphur, combines with the oxygen of the atmoſphere, and forms water. By degrees, however, a portion of the ſulphur is alſo converted into an acid; and when the proportion of ſulphurated hydrogen is diminiſhed, and that of the ſulphur increaſed to a certain point, the ſulphur and the hydrogen combine equally with oxygen.

If ſulphuric or muriatic acids be poured upon a hydroſulphuret after it has been for ſome time expoſed to the air, a quantity of ſulphurated hydrogen gas exhales, ſulphur is depoſited, and after an interval of time ſulphurous acid is diſengaged. It is therefore ſulphurous, and not ſulphuric acid, which is formed while the hydroſulphuret ſpontaneouſly abſorbs oxygen. This acid, however, is not perceptible till after a certain interval of time when ſeparated from the hydroſulphuret by means of an acid; becauſe as long as it meets with ſulphurated hydrogen a reciprocal decompoſition takes place. The oxygen of the acid combines with the hydrogen of the gas, and the ſulphur of both is precipitated.

865 Metalline hydroſulphurets.

Sulphurated hydrogen is capable of combining with ſeveral of the metals, mercury, for inſtance, and ſilver: it combines with the greater number of the metallic oxyds, and forms hydroſulphurets, on which the alkalies have no action at the temperature of the atmoſphere: But concentrated acids combine with the oxyds of theſe hydroſulphurets, and ſeparate the ſulphurated hydrogen in the form of gas.

In the greater number of theſe metallic oxyd hydroſulphurets, the tendency which oxygen and hydrogen have to combine occaſions a partial decompoſition of the ſulphurated hydrogen, and brings the oxyds nearer to the metallic ſtate. In ſome of theſe hydroſulphurets part of the ſulphur alſo combines with oxygen, and forms ſulphuric acid.

The alkaline hydroſulphurets precipitate all the metals from their combination with acids; they are therefore very valuable teſts of the preſence of metals in any ſolution, as they do not precipitate any of the earths except alumina and jargonia. The following table exhibits a view of the effect of hydroſulphuret of potaſs, hydrogenous ſulphuret of potaſs, and water impregnated with ſulphurated hydrogen gas, upon various metallic ſolutions.

Hydroſulphurets.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydroſulphuret of Potaſs.
Green ſulphat of iron.	A black precipitate, which becomes yellow by the contact of the air.		A black precipitate. The potaſs ſeparated.
Red oxyd of iron.		Becomes black. The liquor remains very deep coloured if there be an exceſs of ſulphurated hydrogen.	Becomes black.
Sulphat of zinc.	A white precipitate.	A white precipitate.	A white precipitate.
Acetite of lead.	A white precipitate, which by an addition becomes black.	A black precipitate.	A black precipitate.
Red oxyd of lead.		Becomes black.	The potaſs ſeparated.
Nitrat of biſmuth.		A black precipitate.	A black precipitate.
Oxyd of biſmuth.		Becomes black.	
Nitrat of ſilver.	A black precipitate.	A black precipitate.	A black precipitate.
Sulphat of copper.	A brown precipitate.	A black precipitate.	A black precipitate.
Green oxyd of copper.		Becomes black.	Separation of the potaſs.
Nitrat of mercury.	In a great deal of water, a brown colour.	A browniſh black precipitate.	A browniſh black precipitate.
Oxy-muriat of mercury.	A white precipitate, which becomes black by addition.	A white precipitate, becoming black by an addition.	White becomes black by addition.
Red oxyd of mercury.		Blackiſh.	A heat produced which cauſed the hydroſulphuret to boil. The alkali ſeparated (A).
Muriat of tin.			A black precipitate.
Oxy-muriat of tin.	A precipitation of ſulphur, and of the oxyd.	No change.	A precipitate of white oxyd of tin, and a diſengagement of ſulphurated hydrogen gas.
White oxyd of tin.		No change.	Diſengagement of ſulphurated hydrogen gas.
Sulphat of manganeſe.		No change.	A white precipitate.
Black oxyd of manganeſe.		The odour diſappears. An exceſs of the water diſſolves the oxyd.	Ammonia diſengaged. Heat. The liquor boils (A).
Nitrat of antimony.			A reddiſh orange precipitate.
Tartrite of antimony.	A yellow orange precipitate.	An orange colour, but no precipitate.	An orange red precipitate, rediſſolved by an exceſs of hydroſulphuret.
White oxyd of antimony.		Becomes yellow after ſome ſeconds.	The liquor loſes its colour (A).

Metallic

(A) In theſe, hydroſulphuret of ammonia was uſed inſtead of hydroſulphuret of potaſs.

Table continued.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potaſs.	Water impregnated with Sulphurated Hydrogen Gas.	Hydroſulphuret of Potaſs.
Oxyd of antimony ſublimed.		Scarcely changes colour.	
Solution of oxyd of arſenic.	Sulphuret decompoſed as by an acid.	Becomes ſomewhat muddy, and of a yellow colour.	A yellow colour, but no precipitate.
Sulphat of titanium.			A precipitate of a deep green.
Molybdic acid.		A brown precipitate.	A brown precipitate.

Chap. IV. *Of* Crystallization.

866 ryſtals

The word *Cryſtal* in its ſtrict and proper ſenſe ſignifies a tranſparent body poſſeſſed of a regular figure. But it is now uſed to denote a body which has aſſumed a regular figure whether it be tranſparent or not. *Cryſtallization* is the *act* by which this regular figure is formed.

As the greater number of cryſtals belong to the claſs of neutral ſalts, it may not be improper before we conclude this part of the article to make a few obſervations on the phenomena of cryſtallization.

As cryſtallization is confeſſedly nothing elſe than the regular arrangement of the particles of bodies, it is evident that before it can take place the particles of the body to be cryſtallized muſt be at ſome diſtance from each other, and that they muſt be at liberty to obey the laws of attraction. They may be put into this ſituation 867 by three methods, ſolution, ſuſpenſion and fuſion.

med by ution,

1. Solution is the common method of cryſtallizing ſalts. They are diſſolved in water: The water is ſlowly evaporated, the ſaline particles gradually approach each other, combine together, and form ſmall cryſtals; which become conſtantly larger by the addition of other particles till at laſt they fall by their gravity to the bottom of the veſſel. It ought to be remarked, however, that there are two kinds of ſolution, each of which preſents different phenomena of cryſtallization. Some ſalts diſſolve in very ſmall proportions in cold water, but are very ſoluble in hot water; that is to ſay, water at the common temperature has little effect upon them, but water combined with caloric diſſolves them readily. When hot water ſaturated with any of theſe ſalts cools, it becomes incapable of holding them in ſolution: the conſequence of which is, that the ſaline particles gradually approach each other and cryſtallize. Sulphat of ſoda is a ſalt of this kind. To cryſtallize ſuch ſalts nothing more is neceſſary than to ſaturate hot water with them, and ſet it by to cool. But were we to attempt to cryſtallize them by evaporating the hot water, we ſhould not ſucceed; nothing would procured but a ſhapeleſs maſs. Many of the ſalts which follow this law of cryſtallization combine with a great deal of water; or, which is the ſame thing, many cryſtals formed in this manner contain a great deal of water of cryſtallization.

There are other ſalts again which are nearly equally ſoluble in hot and cold water; common ſalt for inſtance. It is evident that ſuch ſalts cannot be cryſtallized by cooling; but they cryſtallize very well by evaporating their ſolution while hot. Theſe ſalts generally contain but little water of cryſtallization. 868

Suſpenſion,

2. It appears, too, that ſome ſubſtances are capable of aſſuming a cryſtalline form merely by having their particles ſuſpended in water, without any regular ſolution; at leaſt it is not eaſy, on any other ſuppoſition, to explain the cryſtallizations of carbonat of lime ſometimes depoſited by waters that run over quantities of that mineral. 869

And fuſion.

3. There are many ſubſtances, however, neither ſoluble in water, nor capable of being ſo minutely divided as to continue long ſuſpended in that fluid; and which, notwithſtanding, are capable of aſſuming a cryſtalline form. This is the caſe with the metals, with glaſs, and ſome other bodies. The method employed to cryſtallize them is *fuſion*, which is a ſolution by means of caloric. By this method the particles are ſeparated from one another; and if the cooling goes on gradually, they are at liberty to arrange themſelves in regular cryſtals. There are many ſubſtances, however, which it has been hitherto impoſſible to reduce to a cryſtalline form, either by theſe or any other method. Whether this be owing to the nature of theſe bodies themſelves, or to our ignorance of the laws by which cryſtals are formed as is much more likely, cannot be determined. 870

Cryſtallization explained.

The phenomena of cryſtallization ſeem to have attracted but little of the attention of the ancient philoſophers. Their theory indeed, that the elements of bodies poſſeſs certain regular geometrical figures, may have been ſuggeſted by theſe phenomena; but we are ignorant of their having made any regular attempt to explain them. The ſchoolmen aſcribed the regular figure of cryſtals to their ſubſtantial forms, without giving themſelves much trouble about explaining the meaning of the term. This notion was attacked by Boyle; who proved, that cryſtals were formed by the mere aggregation of particles†. But it ſtill remained to explain, why that aggregation took place? and why the particles united in ſuch a manner as to form regular figures? Theſe queſtions were anſwered by Newton. According to him, the aggregation is produced by the attraction which he had proved to exiſt between the particles of all bodies, and which acts as ſoon as theſe particles are brought within a certain diſtance of each other by the evaporation of the liquid in which they are diſſolved. The regularity of their figures he explained by ſuppoſing, that while in a ſtate of ſolution, they were arranged in the liquid in regular rank and file; the conſequence a ſimilar ſegment in the part to which the next edge *c n* belonged, employed for that purpoſe the blade of a knife directed in the ſame degree of obliquity as the trapezium *p s u t*, and aſſiſted by the ſtrokes of a hammer. He could not ſucceed: But upon making the attempt upon the next edge *b c*, he detached another ſegment preciſely ſimilar to the firſt, and which had for its vertex the edge *b c*. He could produce no effect on the next edge *a b;* but from the next following, *a h*, he cut a ſegment ſimilar to the other two. The ſixth edge likewiſe proved refractory. He then went to the other baſe of the priſm *d e f g h r*, and found, that the edges which admitted ſections, ſimilar to the preceding ones were not the edges *e f*, *d r*, *g k*, correſponding with thoſe which had been found diviſible at the oppoſite baſe, but the intermediate edges *d e*, *k r*, *g f*. The trapezium *l q y v* repreſents the ſection of the ſegment, which had *k r* for its vertex. This ſection was evidently parallel to the ſection *p s u t;* and the other four ſections were alſo parallel two and two. Theſe ſections were, without doubt, the natural joinings of the layers of the cryſtal. And he eaſily ſucceeded in making others parallel to them, without its being poſſible for him to divide the cryſtal in any other direction. In this manner he detached layer after layer, approaching always nearer and nearer the axis of the priſm, till at laſt the baſes diſappeared altogether, and the priſm was converted into a ſolid OX (fig. 9.) terminated by twelve pentagons, parallel two and two; of which thoſe at the extremities, that is to ſay, ASRIO, IGEDO, BAODC at one end, and FKNPQ, MNPXU, ZQPXY at the other, were the reſults of mechanical diviſion, and had their common vertices O, P ſituated at the centre of the baſes of the original priſm. The ſix lateral pentagons RSUXY, ZYRIG, &c. were the remains of the ſix ſides of the original priſm.

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† *Treatiſe on the Origin of Forms and Qualities.*

By continuing ſections parallel to the former ones, the lateral pentagons diminiſhed in length; and at laſt the points R, G coinciding with the points Y, Z, the points S, R with the points U, Y, &c. there remained nothing of the lateral pentagons but the triangles YIZ, UXY, &c. (fig. 10.). By continuing the ſame ſections, theſe triangles at laſt diſappeared, and the priſm was converted into the rhomboid *a e*. (fig. 11.).

So unexpected a reſult induced him to make the ſame attempt upon more of theſe cryſtals; and he found that all of them could be reduced to ſimilar rhomboids. He found alſo, that the cryſtals of other ſubſtances could be reduced in the ſame manner to certain primitive forms; always the ſame in the ſame ſubſtances, but every ſubſtance having its own peculiar form. The primitive form of fluat of lime, for inſtance, was an octahedron; of ſulphat of barytes, a priſm with rhomboidal baſes; of field ſpath, an oblique angled parallelopiped, but not rhomboidal; of adamantine ſpar, a rhomboid, ſomewhat acute; of blende, a dodecahedron, with rhomboidal ſides, and ſo on.

Theſe muſt be conſidered as the real *primitive forms* of the cryſtals; the other forms which they often aſſume may be called *ſecondary forms.*

The primitive cryſtals obtained by the above proceſs may be divided by ſections parallel to their different ſides: all the matter which ſurrounded this primitive cryſtal may alſo be divided by ſections parallel to the ſides of the primitive cryſtal. It follows from this, that the parts detached by means of theſe ſections are ſimilar, and differ from one another only in ſize, which diminiſhes in proportion to the length that the diviſion is carried. But the diviſion of the cryſtals into ſimilar ſolids has a term, beyond which we ſhould come to the ſmalleſt particles of the body, which could not be divided without chemical decompoſition. It is probable, therefore, that the form of the integrant particles of a body is the ſame with the primitive form of its cryſtals. Here, then, we have a method of diſcovering the form of the particles of bodies; and if this method could be applied to all ſubſtances whatever, it would enable us to aſcertain the affinity of all bodies for each other by accurate calculation. It muſt be allowed, that ſeveral objections might be made to the concluſions of Mr Hauy; but his theory is, on the whole, ſo plauſible, that it would certainly be worth while to extend it, and apply it to the calculation of affinities as far as it is ſuſceptible of the application. If the cryſtals obtained by the above proceſs be the primitive forms, it becomes a queſtion of ſome conſequence to determine in what manner the ſecondary forms are produced.

According to Hauy, all the parts ſuperadded to the primitive cryſtals, in order to form the ſecondary cryſtal, conſiſt of plates, which decreaſe regularly by the ſubtraction of one or more rows of integrant particles, in ſuch a manner, that the number of theſe ranks, and conſequently the form of the ſecondary cryſtal, may be determined by theory (c).

To explain this, let us ſuppoſe that EP (fig. 12.) repreſents a dodecahedron, terminated by equal and ſimilar rhombs; that this dodecahedron is a ſecondary cryſtal, the primitive form of which is a cube: the ſituation of this cube in the dodecahedron may be conceived from fig. 13. The ſmaller diagonals DC, CG, GF, FD, of four ſides of the dodecahedron, united round the ſame ſolid angle L, form the ſquare CDFG. Now there are ſix ſolid angles, compoſed of four plains, to-wit, the angles L, O, E, N, R, P (fig. 12.); and conſequently, by making ſections through the ſmaller diagonals of the ſides that form theſe angles, ſix ſquares will be made apparent, which are the ſix ſides of the primitive cube, three of which are repreſented in fig. 13. CDFG, ABCD, BCGH.

This cube being compoſed of cubic integrant particles, each of the pyramids, LCDFG for inſtance (fig. 13.) which repoſe upon its ſides, muſt alſo, according to the theory, be compoſed of ſimilar cubic particles. To make this appear, let us ſuppoſe that ABFG (fig. 14.) is a cube compoſed of 729 ſmall cubes: Each of its ſides will conſiſt of 81 ſquares, being the external ſides of as many cubic particles, which together conſtitute the cube. Upon ABCD, one of the ſides of this cube, let us apply a ſquare lamina, compoſed of cubes equal to thoſe of which the primitive cryſtal conſiſts, but which has on each ſide a row of cubes leſs than the outermoſt layer of the primitive cube. It will of courſe be compoſed of 49 cubes, 7 on each ſide; ſo that its lower baſe *o n f g* (fig. 15.) will fall exactly on the ſquare marked with the ſame letters in fig. 14.

Above this lamina let us apply a ſecond *l m p u* (fig. 16.),

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(c) The explanation of Bergman is not very different. See his *Opuſc.* vol. ii. diſſ. 1.

16.), compoſed of 25 cubes; it will be ſituated exactly above the ſquare marked with the ſame letters (fig. 14). Upon this ſecond let us apply a third lamina *v x y z* (fig. 17.) conſiſting only of 9 cubes: ſo that its baſe ſhall reſt upon the letters *v x y z* (fig. 14.). Laſtly, on the middle ſquare *r* let us place the ſmall cube *r* (fig. 18.) which will repreſent the laſt lamina.

It is evident, that by this proceſs a quadrangular pyramid has been formed upon the face ABCD (fig. 14.), the baſe of which is this face, and the vertex the cube *r* (fig. 18.). By continuing the ſame operation on the other five ſides of the cube, as many ſimilar pyramids will be formed; which will envelope the cube on every ſide.

It is evident, however, that the ſides of theſe pyramids will not form continued planes, but that, owing to the gradual diminution of the laminæ of the cubes which compoſe them, theſe ſides will reſemble the ſteps of a ſtair. We can ſuppoſe, however (what muſt certainly be the caſe), that the cubes of which the nucleus is formed are exceedingly ſmall, almoſt imperceptible; that therefore a vaſt number of laminæ are required to form the pyramids, and conſequently that the channels which they form are imperceptible. Now DCBE (fig. 19.) being the pyramid reſting upon the face ABCD (fig. 14.), and CBOG (fig. 19.) the pyramid applied to the next face BCGH (fig. 14.) if we conſider that every thing is uniform from E to O (fig. 19.) in the manner in which the edges of the *laminæ of ſuperpoſition* (as the Abbé Hauy calls the laminæ which compoſe the pyramids) mutually project beyond each other, it will readily be conceived, that the face CEB of the firſt pyramid ought to be exactly in the ſame plane with the face COB of the adjacent pyramid; and that therefore the two faces together will form one rhomb ECOB. But all the ſides of the ſix pyramids amount to 24 triangles ſimilar to CEB; conſequently they will form 12 rhombs, and the figure of the whole cryſtal will be a dodecahedron, ſimilar to that repreſented in fig. 12 and 13.

If the decreaſe of the laminæ of ſuperpoſition took place according to a more rapid law, if each lamina had on its circumference, two, three or four rows of cubes leſs than the inferior lamina—in that caſe, the pyramids produced being lower, their adjacent faces would no longer form one plane; and therefore the ſurface of the ſecondary cryſtal would conſiſt of 24 iſoſceles triangles, all inclined towards each other.

In this manner Mr Hauy has ſhewn, that a variety of ſecondary cryſtals are formed, and that their forms vary by means of ſlight variations in the ratio of the *decrement*. Dodecahedral ſulphuret of iron, for inſtance, is formed from a cubic nucleus, by the addition of laminæ, decreaſing, as in the example given above, with this difference, that from every lamina laid upon the face ABCD (fig. 14.) only one row of cubes are ſubtracted at the ſides AD and BC reſpectively; whereas two rows are ſubtracted at each of the ſides AB and CD. The conſequence of this more rapid decrement on two parallel ſides than on the other two will be, that the pyramid raiſed on the face ABCD (fig. 14), inſtead of terminating in a ſingle cube as in the example given above, will terminate in a range of cubes; or (ſuppoſing the cubes infinitely ſmall) inſtead of terminating in a point, it will terminate in a ridge. The pyramid will therefore have for its two ſides, contiguous to AB and DC, two trapeziums, and for its ſides, contiguous to AD and BC, two triangles. Let us ſuppoſe alſo, that with regard to the laminæ of ſuperpoſition which ariſe on the face BCGH (fig. 14), the decrements follow the ſame law, and that each lamina decreaſes by two rows of cubes towards the lines BC and HG, and only by one row towards the lines CG, BH: The pyramid, in that caſe, will be placed in a direction oppoſite to the pyramid on ABCD, the ridge at the vertex of it running parallel to BC: the vertex of the pyramid raiſed upon CDFG muſt be parallel to CG: the pyramids on the three other ſides of the cube ought to ſtand each like that which ariſes on the oppoſite face.

The ſides of all the ſix pyramids thus formed amount to twelve trapeziums and twelve triangles. Every triangle is evidently contiguous and in the ſame plane with a trapezium of the neareſt pyramid; conſequently the ſecondary cryſtal thus formed conſiſts of twelve ſides, each of which is a pentagon.

Several other examples have been given by Mr Hauy; but theſe are ſufficient to ſhew in what manner the various ſecondary forms of cryſtals are conſtructed, according to the theory of that ingenious philoſopher.

In his reſearches on this ſubject, Mr Hauy perceived, that ſome cryſtals aſſumed ſecondary forms which could not be accounted for by any decrement whatever along the edges. Thus, for inſtance, ſome bodies, the primary form of which is cubic, are ſometimes found cryſtallized in regular octagons. Mr Hauy explains the formation of theſe ſecondary cryſtals, by ſuppoſing that the decrement took place parallel, not to the edges, but to the diagonals of the faces of the primary cubes.

In order to comprehend this, let us ſuppoſe ABCD (fig. 20.) to be the ſurface of a lamina compoſed of ſmall cubes, the baſes of which are repreſented by the little ſquares in the figure. It is evident, that the cubes *a, b, c, d, e, f, g, h, i,* are in the direction of the diagonal of the ſquare ABCD; that the row of cubes *q, v, k, u, x, y, z,* is parallel to the diagonal; as alſo the row *n, t, l, m, p, o, r, s*; and that the whole figure might be divided into rows of ſquares, each of which would be parallel either to the diagonal AC or DB.

Now we may conceive that the laminæ of ſuperpoſition, inſtead of decreaſing by rows of cubes parallel to the edges AB, AD, decreaſe by rows parallel to the diagonals.

Let it be propoſed to conſtruct around the cube AB GF (fig. 21.), conſidered as a nucleus, a ſecondary ſolid, in which the laminæ of ſuperpoſition ſhall decreaſe on all ſides by ſingle rows of cubes, but in a direction parallel to the diagonals. Let ABCD (fig. 22.), the ſuperior baſe of the nucleus, be divided into 81 ſquares, repreſenting the faces of the ſmall cubes of which it is compoſed. Figure 23. repreſents the ſuperior ſurface of the firſt laminæ of ſuperpoſition; which muſt be placed above ABCD (fig. 22.), in ſuch a manner that the points *a,′ b′, c′, d″*, (fig. 23.) anſwer to the points *a, b, c, d,* (fig. 22.). By this diſpoſition the ſquares A *a*, B *b*, C *c*, D *d* (fig. 22.) which compoſe the four outermoſt rows of ſquares parallel to the diagonals AC, BD, remain uncovered. It is evident alſo, that the borders QV, ON, IL, GF (fig. 23.), project by one range beyond the borders AB, AD, CD, BC (fig. 22.), which is neceſſary, that the nucleus may be enveloped towards theſe edges: For if this were not the
caſe,

Coluſion.

We have now finiſhed the three firſt parts of this article, which comprehend all the elementary part of chemiſtry. We ought now to proceed to the fourth part, which was to conſiſt of a chemical examination of ſubſtances as they exiſt in nature in the mineral, vegetable, and animal kingdoms; but this, for various reaſons we ſhall defer till we come to the words MINERALOGY, and *Animal and Vegetable* SUBSTANCES.

We ſhall finiſh this article with a few remarks upon the chemical nomenclature, which for ſome time paſt has been an object of ſerious attention.

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Chemiſtry was unfortunately firſt cultivated by a ſet of ignorant men, filled with the higheſt notions of their own importance, and buoyed up with the mighty feats which they were to perform by their art. The little which they did know they were anxious to conceal; and their anxiety was no leſs to inſpire the world with high ideas of their knowledge and power. The conſequence of this was, that they loaded chemiſtry with the moſt ridiculous and whimſical names that can well be conceived. *Liver of ſulphur*, *mercury of life*, *horned moon*, *butter of antimony*, *the double ſecret*, *the corraline ſecret*, *the ſecret of vitriol*, *the wonderful ſalt*, *the ſecret ſalt*, *the ſalt with many virtues*, *the ſalt of two ingredients*, *the foliated earth of tartar*, were the names by which they diſtinguiſhed ſome of the moſt familiar preparations; and, were it worth while, a great many more names of the ſame ſtamp might eaſily be added.

As ſoon as chemiſtry had attracted the attention of men of ſcience, the abſurdity of its nomenclature was felt, and ſeveral partial improvements were at different times made in it. Macquer, in particular, diſcarded many of the ancient names, and ſubſtituted others leſs exceptionable in their place.

But ſoon after the publication of the firſt edition of his Dictionary, an evil began to be felt ſeverely, which never could have occurred to the earlier chemiſts. Hitherto the number of objects which had engaged the attention of thoſe who cultivated the ſcience had been very limited; the acids amounted only to five; the earths to four, the metals to 12 or 14, and the neutral ſalts ſcarcely exceeded 20 or 30. To remember names for ſo ſmall a number of bodies, however ridiculous they happened to be, was no very difficult matter. But about that time, in conſequence chiefly of the diſcovery of fixed air by Dr Black, which laid the foundation of pneumatic chemiſtry, the ſcience began to extend itſelf, and to enlarge its boundaries with inconceivable rapidity. The number of bodies connected with it, and which it had to deſcribe, ſoon became immenſe; and if every one of them received names not dependant upon one another, the moſt retentive memory could not have remembered the thouſandth part of them.

The difficulty of ſtudying chemiſtry from that time till the year 1782 muſt have been very great: it was even perceived and complained of by the maſters of the ſcience. In 1782 Mr de Morveau, who had undertaken the chemical part of the *Encyclopedie Methodique*, publiſhed in the *Journal de Phyſique* a new chemical nomenclature, and at the ſame time invited all thoſe perſons who were fond of chemiſtry, and intereſted in its progreſs, to propoſe objections and improvements.

This new nomenclature was formed agreeably to the five following rules:

Concluſion.

1. Every ſubſtance ought to have a name, and not to be denoted by a phraſe.
2. Names ought to be as much as poſſible conformable to the nature of the things ſignified by them.
3. When the character of a ſubſtance is not well enough known to determine the denomination, a name which has no meaning is preferable to one which conveys a falſe idea.
4. In the choice of new words, thoſe ought to be preferred which have their roots in the dead languages moſt generally known, that the word may be eaſily ſuggeſted by the ſenſe, and the ſenſe by the word.
5. The new words ought to be as ſuitable as poſſible to the genius of the languages for which they are formed.

This nomenclature was approved of by Macquer, and by Bergman, who had himſelf propoſed one upon a plan not very different (D). He wrote to Morveau, and exhorted him to proſecute his undertaking with courage. "Do not ſpare (ſays he) a ſingle improper denomination; thoſe that are already learned will be always ſo, and thoſe that are not will learn the ſooner*."

This nomenclature was adopted by ſeveral chemiſts, and it was uſed in the greateſt part of the firſt volume of the chemical part of the *Encyclopedie Methodique*; but the new diſcoveries in chemiſtry had produced a more accurate method of reaſoning, and had enabled Lavoiſier to explain the phenomena of the ſcience without the aſſiſtance of the hypothetical principle of phlogiſton, which had hitherto been neceſſary. As the language, even in its improved ſtate, was accommodated to this principle, and preſuppoſed its exiſtence, new changes became evidently neceſſary, in order that, according to Morveau's rule, the words might denote the moſt eſſential properties of the things intended to be ſignified. Accordingly, when Morveau was in Paris in 1787, Lavoiſier, Berthollet, and Fourcroy, agreed to labour in concert with him to bring the chemical nomenclature ſtill nearer to perfection. Theſe philoſophers, aſſiſted by the mathematicians of the Royal Academy and by ſeveral chemiſts, formed a new nomenclature, which they made public in 1787.

For ſome time little attention was paid to this nomenclature by foreign chemiſts, and it ſeemed generally to be diſapproved. The adherents of the phlogiſtic ſyſtem in France, who were exceedingly numerous, viewed it as an engine artfully formed to undermine and deſtroy their favourite theory. They reſolved, therefore, unanimouſly, to cruſh, if poſſible, this new inſtrument, which they conſidered as

——— *in noſtros fabricata machina muros,*
Inſpectura domos, venturaque deſuper urbi.

And for this purpoſe they exerted themſelves with a vigour, which was only equalled by the zeal and indefatigable exertions of their antagoniſts. A kind of civil war was thus kindled in the republic of letters, which was carried on with great animoſity: And poſterity will ſee, with regret, men of undoubted genius at times diveſting themſelves of the armour of truth and of candour, and endeavouring to ſerve their party, and ſtab their adverſaries with darts ſteeped in the poiſon of calumny and falſehood*. This conteſt, however, which was not confined to France, was productive of good effects, which infinitely ſurpaſſed all the bad ones. It occa-

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(D) See his thoughts on a natural hiſtory of foſſils in the 4th vol. of his *Opuſc.*

* *Encycl. Method. Chim.* Preface.

* See the *Jour. de Phyſ.* for 1788, 89, 90, 91, *paſſim.*

Concluſion.

occaſioned an accumulation of facts, produced a rigid examination of the theories and opinions, introduced an accuracy into chemical experiments which has been of the moſt eſſential ſervice, and gave that tone and vigour to the cultivators of chemiſtry which have brought to light the moſt ſublime and unlooked for truths. It deſerves attention, and the fact is no inconſiderable evidence in favour of the antiphlogiſtic theory, that almoſt all the illuſtrious chemiſts who at preſent adhere to it declared originally againſt it. Berthollet, Morveau, Black, Kirwan, and many other chemiſts, who are now its ableſt defenders, were at firſt its moſt powerful opponents. "This ſyſtem had hardly been publiſhed in France (ſays Dr Prieſtley, who ſtill continues to adhere to the doctrine of phlogiſton) before the principal philoſophers and chemiſts of England, notwithſtanding the rivalſhip which has long ſubſiſted between the two countries, eagerly adopted it. Dr Black, in Edinburgh, and as far as I hear, all the Scots, have declared themſelves converts, and, what is more, the ſame has been done by Mr Kirwan, who wrote a pretty large treatiſe in oppoſition to it. The Engliſh reviewers of books, I perceive, univerſally favour the new doctrine. In America, alſo, I hear of nothing elſe. It is taught, I believe, in all the ſchools on this continent, and the old ſyſtem is entirely exploded. And now that Dr Crawford is dead, I hardly know of any perſon except my friends of the Lunar Society at Birmingham, who adhere to the doctrine of phlogiſton; and what may now be the caſe with *them* in this age of revolutions, philoſophical as well as civil, I will not at this diſtance anſwer for.

"It is no doubt *time*, and of courſe opportunity of examination and diſcuſſion, that gives ſtability to any principles. But this new theory has not only kept its ground, but has been conſtantly and uniformly advancing in reputation more than *ten years*, which, as the attention of ſo many perſons, the beſt judges of every thing relating to the ſubject, has been unremittingly given to it, is no inconſiderable period. Every year of the laſt twenty or thirty has been of more importance to ſcience, and eſpecially to chemiſtry, than any ten in the preceding century†."

Introduction.

We have endeavoured in the preceding article to ſtate the different theories which have ſucceſſively made their appearance in *chemiſtry* with as much fairneſs as poſſible. If we have ſucceeded, the reader will be enabled to judge for himſelf which of theſe theories is the moſt conſiſtent with truth; or rather, if we have ſucceeded, he will join with us in thinking that the theory of Lavoiſier is in moſt points an accurate account of what takes place in nature.

This we conſider as a ſufficient reaſon for having adopted the new nomenclature; for as Morveau long ago obſerved, moſt of the objections that were made to it were rather levelled at the doctrine of thoſe who formed it, than at the nomenclature itſelf. Its ſuperiority to every other nomenclature cannot be diſputed for an inſtant; and the vaſt facility which it has added to the acquiſition of chemiſtry, muſt be acknowledged by every one who knows any thing about the ſcience. The table of the new nomenclature will not be expected here, as it has been already given in the Appendix to the article CHEMISTRY in the *Encyclopædia*. At any rate, it would have been unneceſſary, as we have uſed the new names all along; and therefore our readers muſt by this time be well acquainted with them.

Upon the almoſt infinite number of criticiſms which have been made on the new nomenclature, and the many new terms which ſince its publication have been ſucceſſively propoſed, we do not mean to enter. Few of theſe terms can bear a compariſon with the French nomenclature, and ſtill fewer have any claim to be preferred to it; and the philoſophers who perſiſt in theſe uſeleſs innovations, are more probably actuated by the deſire of appearing to have a ſhare in the great revolution which chemiſtry has undergone, than by any hopes of being able to improve the accuracy or the elegance of its language. How few have diſplayed the magnanimity of an illuſtrious philoſopher of our own country, who, though he had invented a new nomenclature himſelf, exhorted his pupils not to uſe it, but to adopt that of the French chemiſts, which was likely ſoon to come into univerſal uſe.

Even the etymological remarks which have been made on the new nomenclature, we conſider as either of little conſequence or as ill-founded. The philoſophers who formed it have diſplayed a ſagacity and a moderation which could not be excelled, and have, upon the whole, formed a language much more ſyſtematic, and much more perfect, than could have been expected; and whoever compares it with the nomenclature propoſed in 1782 by Morveau, will ſee how great a ſhare of it is due to that illuſtrious and candid philoſopher.

Notwithſtanding what we have here ſaid, we would not be underſtood to conſider the new nomenclature as already arrived at a ſtate of ſuch abſolute perfection, that no alteration whatever can be made in it except for the worſe. Such perfection belongs not to the works of man; nor if it did, could it be expected in this caſe, if we conſider for a moment the preſent ſtate of chemiſtry. New diſcoveries muſt occaſion additions and alterations in the nomenclature; but the authors of the new nomenclature have given us the rules by which changes and additions are to be made; and if they are adhered to, we may expect with confidence that the language of chemiſtry will in its advancement to perfection keep pace with the ſcience. We have in the preceding article ventured in an inſtance or two to adopt little improvements that have been ſuggeſted by later writers. We have taken the liberty, too, of chooſing, from the variety which the Britiſh chemiſts have propoſed, that mode of ſpelling each of the terms which appeared to us moſt agreeable to the Engliſh idiom, and moſt conformable to analogy: Whether or not we have made a proper choice muſt be left for others to determine.

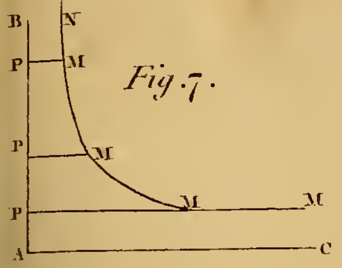
---

† *Conſiderations on the doctrine of phlogiſton*,

Erratum in the article Chemiſtry.

In page 305. *dele* the whole account of *Adamanta*, the exiſtence of which as a peculiar earth has been deſtroyed by the ſubſequent experiment of *Klaproth*. It may be proper to mention, that in that ſection, n° 239. line 2. *infuſible* ought to be *fuſible*.

Fig. 7.



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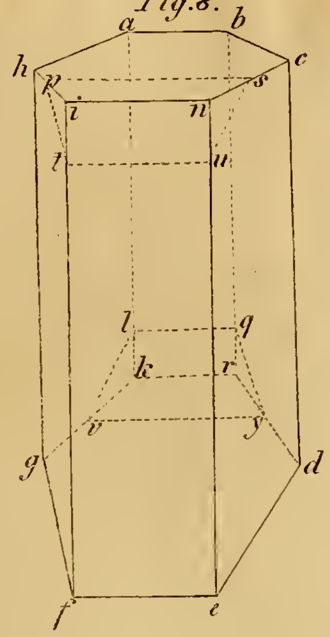

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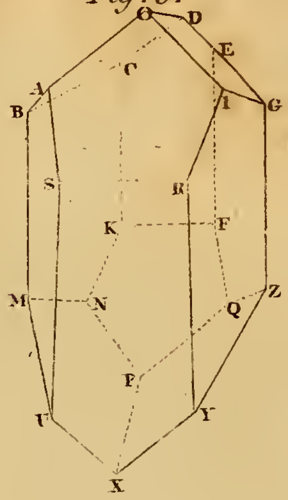

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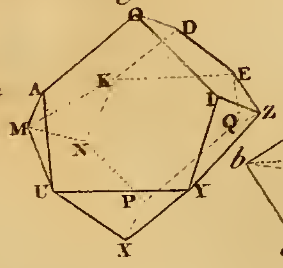

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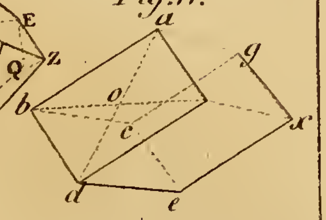

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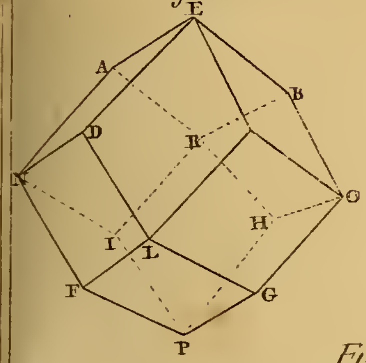

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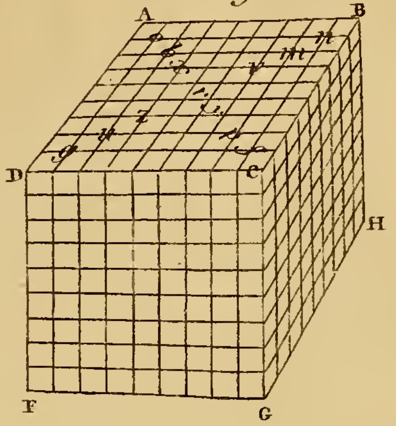

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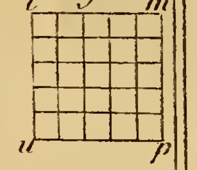

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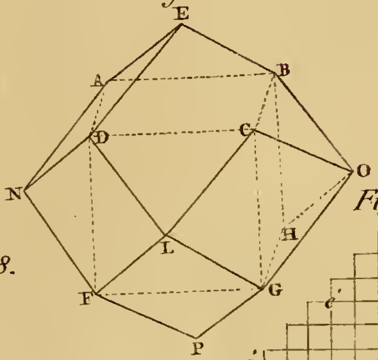

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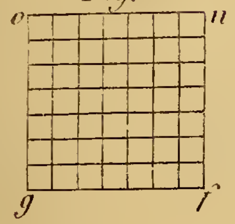

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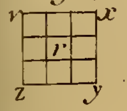
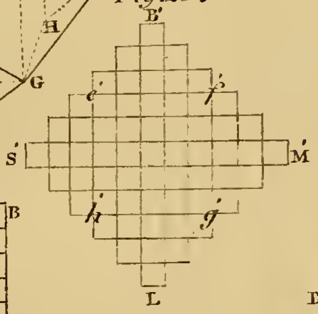


Fig. 18.

Fig. 25.



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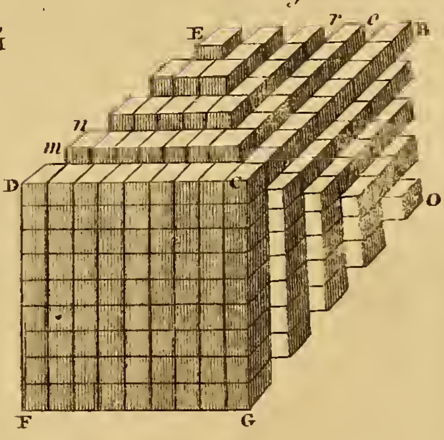

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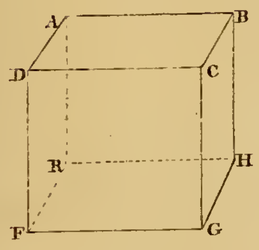

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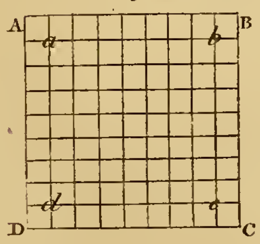

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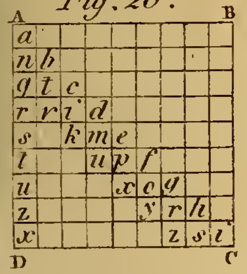

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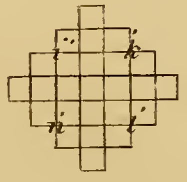

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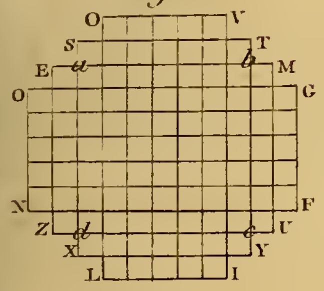

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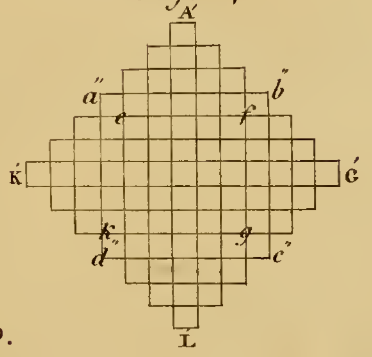

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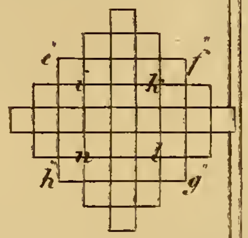

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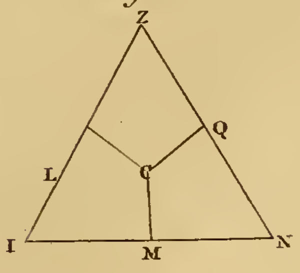

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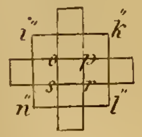
Fig. 28.



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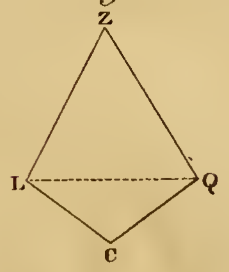
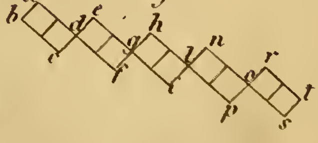


Fig. 30.

Fig. 33.



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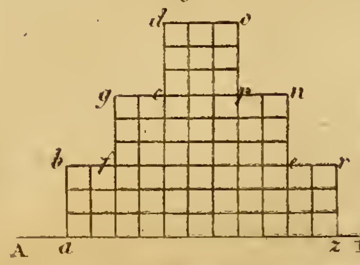

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CHEMUNG, is a townſhip in Tioga co. New-York. By the ſtate cenſus of 1796, 81 of its inhabitants were electors. It has Newton W. and Oſwego E. about 160 miles N. W. from New-York city, meaſuring in a ſtraight line.

Between this place and Newton, Gen. Sullivan, in his victorious expedition againſt the Indians, in 1779, had a deſperate engagement with the Six Nations, whom he defeated. The Indians were ſtrongly intrenched, and it required the utmoſt exertions of the American army, with field pieces, to diſlodge them; although the former, including 250 tories, amounted only to 800 men, while the Americans were 5000 in number, and well appointed in every reſpect.—*Morſe.*

CHENENGO, is a northern branch of Suſquehanna River. Many of the military townſhips are watered by the N. W. branch of this river. The towns of Fayette, Jerico, Greene, Clinton, and Chenengo, in Tioga co. lie between this river and the E. waters of Suſquehanna.—*ib.*

Chenengo, a poſt town, and one of the chief in Tioga co. New-York. The ſettled part of the town lies about 40 miles N. E. from Tioga point, between Chenengo River and Suſquehanna; has the town of Jerico on the northward. By the ſtate cenſus of 1796, 169 of its inhabitants are electors. It was taken off from Montgomery co. and in 1791, it had only 45 inhabitants. It is 375 miles N. N. W of Philadelphia.—*ib.*

CHENESSEE, or *Geneſſee River* riſes in Pennſylvania, near the ſpot which is the higheſt ground in that ſtate, where the eaſternmoſt water of Alleghany river, and Pine creek, a water of Suſquehannah, and Tioga river riſe. Fifty miles from its ſource there are falls of 40 feet, and 5 from its mouth of 75 feet, and a little above that of 96 feet. Theſe falls furniſh excellent mill-ſeats, which are improved by the inhabitants. After a courſe of about 100 miles, moſtly N. E. by N. it empties into lake Ontario, 4½ miles E. of Irondequat or Rundagut bay, and 80 E. from Niagara falls.

The ſettlements on Cheneſſee river from its mouth upwards, are, Hartford, Ontario, Wadſworth and Williamſburgh. The laſt mentioned place, it is probable, will ſoon be the ſeat of extenſive commerce. There will not be a carrying place between New-York city and Williamſburgh, when the weſtern canals and locks ſhall be completed. The carrying places at preſent are as follows, viz. Albany to Schenectady 16 miles, from the head of the Mohawk to Wood creek 1, Oſwego falls 2, Cheneſſee falls 2; ſo that there are but 21 miles land carriage neceſſary, in order to convey commodities from a tract of country capable of maintaining ſeveral millions of people. The famous Cheneſſee flats lie on the borders of this river. They are about 20 miles long, and about 4 wide; the ſoil is remarkably rich, quite clear of trees, producing graſs near ten feet high. Theſe flats are eſtimated to be worth £.200,000, as they now lie. They are moſtly the property of the Indians.—*ib.*

CHEPAWAS, or *Chipeways*, an Indian nation inhabiting the coaſt of lake Superior and the iſlands in the lake.

cherub at the other end: מן הכפרת out of the mercy-ſeat (Margin Eng. Tranſlat. of the matter of the mercy-ſeat) ſhall ye make the cherubs at the two ends thereof.' All which was accordingly performed (Exod. xxxvii. 7, 8.), and theſe cherubs were with the ark placed in the holy of holies of the tabernacle (Exod. xxvi. 33, 34. xl. 20.); as thoſe made by Solomon were afterwards in the holy of holies of the temple (1 Kings vii. 23, 27.)

We may obſerve that in Exodus Jehovah ſpeaks to Moſes of the cherubs as of figures well known; and no wonder, ſince they had always been among believers in the holy tabernacle from the beginning. (See Gen. iii. 24. Wiſd. ix. 8. And though mention is made of their faces (Exod. xxv. 20. 2 Chron. iii. 13.), and of their wings, (Exod. xxv. 20. 1 Kings, viii. 7. 2 Chron. iii. 11, 12.); yet neither in Exodus, Kings, nor Chronicles have we any particular deſcription of their form. This is however very exactly, and as it were, anxiouſly ſupplied by the prophet Ezekiel, ch. i. 5. 'Out of the midſt thereof (*i. e.* of the fire infolding itſelf, ver. 4.) דמות the likeneſs of four living creatures or animals; דמות אדם להנה the likeneſs of a man (being) with them.' This laſt Hebrew expreſſion cannot mean that they, *i. e.* the four animals, had the likeneſs of a man, which interpretation would indeed make the prophet contradict himſelf (comp. ver. 10.); but it imports that the likeneſs of a man in glory, called (verſe 26.) דמות כמראה אדם the likeneſs as the appearance of a man, and particularly deſcribed in that and the following verſes was with them. Ver. 6. 'And there were four faces to one (דמות or ſimilitude), and four wings to one, להם to them.' So there were at leaſt two compound figures. Ver 10. 'And the likeneſs of their faces; the face of a man, and the face of a lion, on the right ſide, to them four; and the face of an ox to them four; and the face of an eagle to them four.' Ezekiel knew (ch. x. 1--20.) that theſe were cherubs. Ver. 21. 'Four faces לאחד to one (cherub) and four wings to one.' This text alſo proves that the prophet ſaw more cherubs than one, and that each had four faces and four wings. And we may be certain that the cherubs placed in the holy of holies were of the form here deſcribed by the prieſt and prophet Ezekiel, becauſe we have already ſeen from Exodus, 1 Kings, and 2 Chronicles, that they likewiſe had faces and wings, and becauſe Ezekiel knew what he ſaw to be cherubs, and becauſe there were no four-faced cherubs any where elſe but in the holy of holies; for it is plain, from a compariſon of Exod. xxvi. 1, 31. 1 Kings vi, 29, 32, and 2 Chron. iii. 14. with Ezekiel xli. 18, 19, 20. that the artificial cherubs on the curtains and vail of the tabernacle, and on the walls, doors, and vail of the temple, had only two faces; namely, thoſe of a lion and of a man.

"For it muſt be obſerved further, that as the word כרוב is uſed for one compound figure with four faces, and כרובים in the plural for ſeveral ſuch compounds (ſee Exod. xxv. 18, 19. xxxvii. 8. 1 Kings vi. 23—26), ſo is כרוב applied to one of the cherubic animals, as to the ox, Ezek. x. 14; (compare ch. i. 10.) to the coupled cherub or lion-man, Ezek. xli. 18.; and כרובים to ſeveral of the cherubic animals as to ſeveral oxen, 1 Kings vii. 36, (compare ver. 29) to ſeveral coupled cherubs, Exod. xxvi. 1. 1 Kings vi. 32, 35. & al. I proceed to ſhew

"*Secondly*, of what the cherubs were emblems, and with what propriety.

"That the cherubic figures were emblems or repreſentatives of ſomething beyond themſelves is, I think, agreed by all, both Jews and Chriſtians. But the queſtion is, of what they were emblematical? To which I anſwer in a word, Thoſe in the holy of holies were emblematical of the ever bleſſed Trinity in covenant to redeem man, by uniting the human nature to the Second Perſon; which union was ſignified by the union of the faces of the lion and of the man in the cherubic exhibition, Ezek. i. 10. compare Ezek. xli. 18, 19. The cherubs in the holy of holies were certainly intended to repreſent ſome beings in heaven, becauſe St Paul has expreſsly and infallibly determined that the holy of holies was a figure or type of heaven, even of that heaven where is the peculiar reſidence of God (Heb. ix. 24). And therefore theſe cherubs repreſented either the ever bleſſed Trinity with the man taken into the eſſence, or created ſpiritual angels. The following reaſons will, I hope, clearly prove them to be emblematical of the former, not of the latter:

"*1ſt*, Not of angels; becauſe (not now to inſiſt on other circumſtances in the cherubic form) no tolerable reaſon can be aſſigned why angels ſhould be exhibited with four faces apiece.

"*2dly*, Becauſe the cherubs in the holy of holies of the tabernacle were, by Jehovah's order, 'made out of the matter of the mercy-ſeat, or beaten out of the ſame piece of gold as that was' (Exod. xxv. 18, 19. xxxvii. 9.). Now the mercy-ſeat made of gold, and crowned, was an emblem of the divinity of Chriſt (See Rom. iii. 25.). The cherubs therefore repreſented not the angelic, but the Divine nature.

"*3dly*, The typical blood of Chriſt was ſprinkled before them on the great day of atonement (compare Exod. xxxviii. 9. Lev. xvi. 14. Heb. ix. 7, 12.): And this cannot in any ſenſe be referred to created angels, but muſt be referred to Jehovah only, becauſe,

"*4thly*, The high prieſt's entering into the holy of holies on that day, repreſented Chriſt's entering with his own blood into heaven, 'to appear in the preſence of God for us' (Heb. ix. 7, 24.). And,

"*5thly*, When God 'raiſed Chriſt (the humanity) from the dead, he ſet him at his own right hand in the heavenly places, far above, ΥΠΕΡΑΝΩ, all principality and power, and might, and dominion, and every name that is named, not only in this world, but alſo in that which is to come (Eph. i. 21.). Angels and authorities and powers being made ſubject unto him' (1 Peter iii. 22.)

"*6thly*, The prophet Ezekiel ſaith (ch. x. 20.), 'This is the living creature, החיה (which muſt mean one compound figure, comp. ver. 14.) that I ſaw' תחת (inſtead of, a ſubſtitute of 'the Aleim of Iſrael. תחת, it is granted, may refer either to ſituation or ſubſtitution, (ſee Gen. xxx. 2. l. 19.) as the ſenſe requires. Here, notwithſtanding what is ſaid ver. 19. the latter ſenſe is preferable, becauſe it was the glory of the God of Iſrael, *i. e.* the God-man in glory, (compare ch. i. 26.) not the Aleim (the Trinity) of Iſrael that were over the cherubim; and the text ſays not, *theſe* were the living *creatures*, but, *this* was the living *creature*, which I ſaw תחת אלהי ישראל. Now the glory was over both the cherubims, ver. 19. but one compound cherub only was a ſubſtitute of the Aleim.

“If it ſhould be here aſked, Why, then, were there two compound cherubs in the holy of holies? I anſwer, Had there not in this place been two compound cherubs, it would have been naturally impoſſible for them to repreſent what was there deſigned; for otherwiſe, all the faces could not have looked inwards toward each other, and down upon the mercy-ſeat, and on the interceding high prieſt ſprinkling the typical blood of Chriſt, (ſee Exod. xxxvii. 9.) and at the ſame time have looked outward toward the temple, לבית (Vulg. ad. domum exteriorem, to the outer houſe,) 2 Chron. iii. 13. Or, in other words, the Divine Perſons could not have been repreſented as witneſſing to each other's voluntary engagements for man's redemption, as beholding the ſacrifice of Chriſt's death, typified in the Jewiſh church, and at the ſame time as extending their gracious regards to the whole world. (See Iſa. liv. 5. and Spearman's Enquiry, p. 382. edit. Edinburgh.)

“The coupled cherub, or lion-man, on the vail, and curtains of the outer tabernacle, and on the vail, doors, and walls of the temple, accompanied with the emblematic palm tree, is ſuch a ſtriking emblem of the lion of the tribe of Judah (Rev. v. 5.) united to the man Chriſt Jeſus, as is eaſy to be perceived, but hard to be evaded. Theſe coupled cherubs appropriate the tabernacle or temple and their vails as emblems of Chriſt, and expreſs in viſible ſymbols what he and his apoſtles do in words. See John ii. 19, 21. Heb. viii. 2. ix. 11. x. 20. comp. Matt. xxvii. 51. And as the texts juſt cited from the New Teſtament afford us divine authority for aſſerting that the outer tabernacle or temple was a type of the body of Chriſt, ſo they furniſh us with an irrefragable argument to prove that the cherubs on their curtains or walls could not repreſent angels. For did angels dwell in Chriſt's body? No ſurely: But ‘in him dwelt all the fulneſs of the Godhead bodily.’ (Col. ii. 9.)

“I go on to conſider the propriety of the animals in the cherubic exhibition repreſenting the Three Perſons in the ever-bleſſed Trinity. And here to obviate any undue prejudice which may have been conceived againſt the Divine Perſons being ſymbolically repreſented under any animal forms whatever, let it be remarked that Jehovah appeared as three men to Abraham, (Gen. xviii.); that the ſerpent of braſs ſet up by God's command in the wilderneſs was a type or emblem of Chriſt, God-man, lifted up on the croſs (comp. Num. xxxi. 1—9. with John iii. 14. 15.); that at Jeſus' baptiſm the Holy Spirit deſcended in a bodily ſhape, like a dove, upon him (Luke iii. 21, 22); that Chriſt, as above intimated, is expreſsly called the lion of the tribe of Judah (Rev. v. 5.); and continually in that ſymbolical book ſet before us under the ſimilitude of a lamb. All theſe are plain ſcriptural repreſentations, each of them admirably ſuited, as the attentive reader will eaſily obſerve, to the particular circumſtances or ſpecific deſign of the exhibition. Why then ſhould it appear a thing incredible, yea why not highly probable, that Jehovah Aleim ſhould, under the typical ſtate, order his own Perſons and the union of the manhood with the eſſence to be repreſented by animal forms in the cherubim of glory? Eſpecially if it be conſidered that the three animal forms, excluſive of the man (who ſtood for the very human nature itſelf) are the chief of their reſpective genera: the ox or bull, of the tame or graminivorous; the lion of the wild or carnivorous; and the eagle, of the winged kind.—But this is by no means all: For as the great agents in nature, which carry on all its operations, certainly are the fluid of the heavens, or, in other words, the fire at the orb of the ſun, the light iſſuing from it, and the ſpirit or groſs air conſtantly ſupporting, and concurring to the actions and effects of the other two; ſo we are told (Pſal. xix. 1.) that השמים מספרים כבוד אל the heavens (are) the means of declaring, recounting, or particularly exhibiting the glory of God, even his eternal power and godhead, as St Paul ſpeaks, Rom. i. 20. And accordingly Jehovah himſelf is ſometimes, though rarely (I preſume for fear of miſtakes) called by the very name שמים or שמיא heavens in the Old Teſtament, ſee 2 Chron. xxxii. 20. (comp. 2 Kings xix. 14. Iſa. xxxvii. 15.) Dan. iv. 23. or 26.; as he is more frequently expreſſed by Ουρανος heaven in the New. (See Mat. xxi. 25. Mark xi. 30, 31. Luke xv. 18, 21. xx. 4, 5. John iii. 27.) Yea not only ſo, but we find in the Scriptures both of the Old and New Teſtament, that the Perſons of the eternal Three and their economical operations in the ſpiritual, are repreſented by the three conditions of the celeſtial fluid and their operations in the material world. Thus the peculiar emblem of the Word or Second Perſon is the שמש or light, and he is and does that to the ſouls or ſpirits of men which the material or natural light is and does to their bodies. (See inter al. 2 Sam. xxiii. 4. Iſa. xlix. 6. lx. 1. Mal. iv. 2. or iii. 20. Luke i. 78. ii. 32. John i. 4—9. viii. 12. xii. 35, 36, 46.) The Third Perſon has no other diſtinctive name in ſcripture but רוח in Hebrew, and Πνευμα in Greek, (both which words in their primary ſenſe denote the material ſpirit or air in motion), to which appellation the epithet קדש, άγιον holy, or one of the names of God, is uſually added: and the actions of the Holy Spirit in the ſpiritual ſyſtem are deſcribed by thoſe of the air in the natural. (See John iii. 8. xx. 22. Acts ii. 2.) Thus, then, the Second and Third Perſons of the ever-bleſſed Trinity are plainly repreſented by ſcripture by the material light and air. But it is further written, Jehovah thy Aleim is a conſuming fire, Deut. iv. 24. (Comp. Deut. ix. 23. Heb. xii. 29. Pſal. xxi. 10. lxxviii. 21. Nah. i. 2.) And by fire, derived either immediately or mediately from heaven, were the typical ſacrifices conſumed under the old diſpenſation. Since, then, Jehovah is in ſcripture repreſented by the material heavens, and even called by their name, and eſpecially by that of fire, and ſince the Second and Third Perſons are exhibited reſpectively by the two conditions of light and ſpirit, and ſince fire is really a condition of the heavenly fluid as much diſtinct from the other two as they are from each other, it remains that the peculiar emblem of the Firſt Perſon (as we uſually ſpeak) of the eternal Trinity, conſidered with reſpect to the other two, be the fire.

“Bearing then in mind that the perſonality in Jehovah is in ſcripture repreſented by the material Trinity of nature; which alſo, like their divine antitype, are of one ſubſtance, that the primary ſcriptural type of the Father is fire; of the Word, light; and of the Holy Ghoſt, ſpirit, or air in motion; we ſhall eaſily perceive the propriety of the cherubic emblems. For the ox or bull, on account of his horns, the curling hair on his forehead, and his unrelenting fury when provoked (ſee Pſal. xxii. 13.) is a very proper animal emblem of fire; as the lion from his uſual tawny gold-like colour, his flowing mane, his ſhining eyes, his great vigilancy and prodigious ſtrength, is of light; and thus likewiſe the eagle is of the ſpirit or air in action, from his being chief among fowls, from his impetuous motion (ſee 2 Sam. i. 23. Job ix. 26. Jer. iv. 13. Lam. iv. 19.), and from his towering and ſurpriſing flights in the air (ſee Job xxxix. 27. Prov. xxiii. 5. xxx. 19. Iſa. xl. 31. and Bochart, vol. iii. page 173.) And the heathen uſed theſe emblematic animals, or the like, ſometimes ſeparate, ſometimes joined, in various manners, as repreſentatives of the material Trinity of nature, which they adored. Theſe particulars Mr Hutchinſon has proved with a variety of uſeful learning, vol. vii. p. 381. & ſeq. and any perſon who is tolerably acquainted with the heathen mythology will be able to increaſe his valuable collection with many inſtances of the ſame kind from modern as well as ancient accounts of the pagan religions.

"Thus, then, the faces of the ox, the lion, and the eagle, repreſenting at ſecond hand the Three Perſons of Jehovah, the Father, the Word, and the Holy Spirit; and the union of the divine light with man being plainly pointed out by the union of the faces of the lion and the man (ſee Ezek. i. 10. xli. 18.), we may ſafely aſſert, that the cherubim of glory (Heb. ix. 5.) in the holy of holies were divinely inſtituted and proper emblems of the Three Eternal Perſons in covenant to redeem man, and of the union of the divine and human natures in the perſon of Chriſt. And we find (Gen. iii. 24.) that immediately on Adam's expulſion from paradiſe, and the ceſſation of the firſt or paradiſiacal diſpenſation of religion, Jehovah Aleim himſelf ſet up theſe emblems, together with the burning flame המתהפכת rolling upon itſelf, to keep the way to the tree of life; undoubtedly, conſidering the ſervices performed before them, not to hinder, but to enable, man to paſs through it."

Thus far Mr Parkhurſt; and to his diſſertation where is the man who will deny the merit of erudition, combined with ingenuity? To the latter part of his reaſoning, however, objections obtrude themſelves upon us of ſuch force, that we know not how to anſwer them. The reader obſerves, that according to this account, the cherubim are only at *ſecond hand* emblematical of the Holy Trinity, and that the *primary* emblem is that fluid which the author conceives to fill the ſolar ſyſtem, and to be one ſubſtance under the different appearances or modifications of *fire*, *light*, and *groſs air*. But unfortunately for this reaſoning, we are as certain as we can be of any matter of fact, that *fire* and *air* are *not* one ſubſtance; that the *groſs air* itſelf is compounded of very *different* ſubſtances; and that even *light* is a different ſubſtance from that which cauſes in us the ſenſation of heat, and to which modern chemiſts have given the name of *caloric* (See CHEMISTRY-*Index* in this Supplement). We admit, that the *primary atoms* of all matter *may be* ſubſtances of the very ſame kind, though we do not *certainly know* that they are: but this makes nothing for our author's hypotheſis; becauſe the ſun and all the planets muſt, in that caſe, be added to his one ſubſtance, which would no longer appear under a triple form. Could it indeed be proved, that all men from Adam downwards, who made uſe of cherubic figures for the very ſame purpoſe with the ancient Jews, *believed* that fire, air, and light, are different modifications of the ſame ſubſtance, their belief, though erroneous, would be a ſufficient foundation for our author's reaſoning: but of this no proof is attempted, and certainly none that is ſatisfactory could be brought.

Our learned author, indeed, takes much for granted without proof. He has not proved, that anywhere the bull was the emblem or hieroglyphic of *fire*, the lion of *light*, or the eagle of *air*. We do not, it muſt be owned, know that ſuch hieroglyphics were *not* uſed in Egypt and other countries before the introduction of alphabetical characters; but unleſs they were ſo uſed by Adam, all that is here ſaid of the *propriety* of theſe emblems muſt go for nothing: Indeed we ſee not their peculiar propriety. The tawny colour, flowing mane, and fierceneſs of the lion, might, for any thing that we can perceive to the contrary, repreſent *fire* as fitly as the horns, curling hair, and fury of the bull; and if it be true, as is generally ſaid, that the eagle can look ſteadily on the ſun, he ſeems, of all the three, to be the fitteſt emblem of light.

But there are other objections to this interpretation of the word cherubim. The four animals in the Revelation, which were undoubtedly cherubim, as well as the four and twenty elders, fell down before the Lamb, and worſhipped God.* Now, ſays Dr Gregory Sharp, "it is ſcarce to be conceived, if theſe four beaſts were repreſentatives of the divine perſons, that they could with any propriety, or without the greateſt ſoleciſm, be ſaid and deſcribed to fall down before and worſhip other emblematical repreſentations of the ſame divine nature and perfections: And therefore, whatever theſe beaſts were emblems of, they could not be cherubim in Mr Hutchinſon's ſenſe of that word; it being as contrary to the rational explanation of a viſion to ſay that one emblem of the divinity ſhould worſhip another emblem of it, as it is contrary to the reaſon of mankind, and to all our notions either of the Godhead or of worſhip, to ſay that the Trinity worſhipped the Trinity, or any one Perſon in the Trinity."

This objection is admitted by our learned author to be a very plauſible one. To us it appears unanſwerable. He anſwers it, however, in the following words:

"Let it be carefully obſerved, that theſe repreſentations in Rev. ch. v. and xix. are not only viſional but hieroglyphical, and therefore muſt be explained according to the analogy of ſuch emblematical exhibitions; and as at ver. 6. 'the lamb, as it had been ſlain, having ſeven horns and ſeven eyes, ſtanding in the midſt of the throne, and of the four animals, and of the four-and-twenty elders,' is evidently ſymbolical of the Lamb of God now raiſed from the dead, and inveſted with all knowledge and power both in heaven and in earth; ſo 'the four animals falling down before him' (ver. 8.), and, as it is expreſſed (ch. xix. 4.) 'worſhipping God who ſat upon the throne,' muſt, in all reaſon, be explained ſymbolically likewiſe, not from any abſtract or metaphyſical notions we may have framed to ourſelves of worſhip in general, but from the ſpecific and peculiar circumſtances of the caſe before us. Thus likewiſe, when in 1 Chron. xxix. 20. 'All the congregation worſhipped Jehovah and the king, namely David, the worſhip to both is expreſſed by the ſame ſtrong phraſe—ישתחוו ל proſtrated themſelves to, LXX. προσεκυνησαν; yet ſurely no one will ſay that the people meant to worſhip David as God, but only to acknowledge him as king. So Adonijah, who had conteſted the crown with Solomon, came, וישתחו and worſhipped King Solomon, (1 Kings 1. 53.) not as God doubtleſs, but as king, thereby ſurrendering his own claim to the throne. However "contrary therefore it may be to the reaſon of mankind, and to all our notions either of the Godhead or of worſhip, to ſay that the Trinity worſhipped the Trinity, or any one Perſon of the Trinity," *i. e.* with divine worſhip as a creature worſhips his Creator; yet it is by no means contrary to the rational and ſcriptural explanation of an emblematic viſion, to ſay that the hieroglyphical emblems of the whole ever-bleſſed Trinity fell down and worſhipped the hieroglyphical emblem of the God-man, or God who ſat upon the throne. Since ſuch falling down, proſtration, or worſhipping, was the uſual ſymbolical act, as it ſtill is in the eaſt, not only of divine worſhip, but of acknowledging the regal power to be in the perſon ſo worſhipped; and theſe acts of the cherubic animals in Rev. v. 6, xix. 4. meant nothing more than either a ceſſion of the adminiſtration of all divine power to Chriſt God-man, or a declaration of the divine Perſons, by their hieroglyphical repreſentatives, that He muſt reign till all his enemies were made his footſtool. Comp. Mat. xxviii. 18. 1 Cor. xv. 25."

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* Ch. v. 8. xix. 4.

With every inclination to honour the memory of Mr Parkhurſt, who was certainly a ſcholar, and, which is of more value, a pious and a good man, we cannot help conſidering this anſwer as mere trifling. In the 18th Pſalm, the Lord is ſaid to "ride upon a cherub;" and in Ezekiel, chap. i. there is ſaid to have "been over the heads of the cherubim *a throne*, and upon that throne the likeneſs or appearance of *a man*," whom we take to be the Son of God incarnate. But is there any country in which the regal power of the ſovereign is acknowledged by his riding, not upon his ſubjects, but upon other co-equal ſovereigns? or, in which it is the cuſtom for the ſovereign to place his viceroy (for ſuch our Saviour in his *human* nature certainly is) in his throne above himſelf?

We muſt therefore confeſs, that we know not of what the cherubic figures were emblematical, and that he who labours to eſtabliſh the doctrine of the ever bleſſed Trinity by ſuch criticiſms and reaſonings as thoſe which we have examined, is either a ſecret enemy to that doctrine, or a very injudicious friend.

CHESAPEAK, is one of the largeſt and ſafeſt bays in the United States. Its entrance is nearly E. N. E. and S. S. W. between Cape Charles, lat. 37. 12. and Cape Henry, lat. 37. in Virginia, 12 miles wide, and it extends 270 miles to the northward, dividing Virginia and Maryland. It is from 7 to 18 miles broad, and generally as much as 9 fathoms deep; affording many commodious harbors, and a ſafe and eaſy navigation. It has many fertile iſlands, and theſe are generally along the E. ſide of the bay, except a few ſolitary ones near the weſtern ſhore. A number of navigable rivers and other ſtreams empty into it, the chief of which are Suſquehanna, Patapſco, Patuxent, Potowmack, Rappahannock, and York, which are all large and navigable. Cheſapeak bay affords many excellent fiſheries of herring and ſhad. There are alſo excellent crabs and oyſters. It is the reſort of ſwans, but is more particularly remarkable for a ſpecies of wild duck, called *canvaſback*, whoſe fleſh is entirely free from any fiſhy taſte, and is admired by epicures, for its richneſs and delicacy. In a commercial point of view, this bay is of immenſe advantage to the neighboring ſtates, particularly to Virginia. Of that ſtate it has been obſerved, with ſome little exaggeration, however, that "every planter has a river at his door."—*Morſe.*

CHEESADAWD *Lake*, about 210 miles N. E. by E. of the Canadian houſe, on the E. end of Slave lake, in the Hudſon bay company's territory; is about 35 miles in length and the ſame in breadth. Its weſtern ſhore is mountainous and rocky.—*ib.*

CHESHIRE *Co.* in New-Hampſhire, lies in the S. W. part of the ſtate, on the E. bank of Connecticut river. It has the ſtate of Maſſachuſetts on the ſouth, Graſton co. on the N. and Hillſborough co. E. It has 34 townſhips, of which Charleſtown and Keene are the chief, and 28,772 inhabitants, including 16 ſlaves.—*ib.*

CHESHIRE, a townſhip in Berkſhire co. Maſſachuſetts; famous for its good cheeſe; 140 miles N. weſterly from Boſton.—*ib.*

CHESHIRE, a townſhip in New-Haven co. Connecticut, 15 miles N. of New-Haven city, and 26 S. W. of Hartford. It contains an Epiſcopal church and academy, and 3 Congregational churches.

CHESNUT *Hill*, a town in Northampton county Pennſylvania, ten miles from Philadelphia and two from Germantown, a fine elevated and healthy ſituation, commanding an extenſive and delightful proſpect of the capital and the ſurrounding country.

CHESNUT *Hill*, a townſhip in Northampton co. Pennſylvania.—*ib.*

CHESNUT *Creek*, a branch of the Great Kanhaway, in Virginia, where it croſſes the Carolina line. Here, it is ſaid, are iron mines.—*ib.*

CHESNUT *Ridge*. Part of the Alleghany mountains, in Pennſylvania, are thus called, S. eaſtward of Greenſborough.—*ib.*

CHESS, the celebrated game, of which a copious account has been given in the Encyclopædia, is affirmed by Sir William Jones to have been invented by the Hindoos. If evidence were required to prove this fact (ſays he*), we may be ſatisfied with the teſtimony of the Perſians, who, though as much inclined as other nations to appropriate the ingenious inventions of a foreign people, unanimouſly agree that the game was imported from the weſt of *India* in the ſixth century of our era. It ſeems to have been immemorially known in *Hindoſtan* by the name of *Cheturanga*, i. e. the four *angá's*, or members of an army; which are theſe, *elephants*, *horſes*, *chariots*, and *foot-ſoldiers*; and in this ſenſe the word is frequently uſed by epic poets in their deſcriptions of real armies. By a natural corruption of the pure Sanſcrit word, it was changed by the old Perſians into *Chetrang*; but the Arabs, who ſoon after took poſſeſſion of their country had neither the initial nor final letter of that word in their alphabet, and conſequently altered it further into *Shetranj*, which found its way preſently into the modern *Perſian*, and at length into the dialects of India, where the true derivation of the name is known only to the learned. Thus has a very ſignificant word in the ſacred language of the

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* *Aſiatic R ſearches*, vo ii. Mem.

Brahmins been transformed by ſucceſſive changes into *axedrez*, *ſcacchi*, *echces*, *cheſs*, and by a whimſical concurrence of circumſtances, has given birth to the Engliſh word *check*, and even a name to the *exchequer* of Great Britain."

It is confidently aſſerted, that Sanſcrit books on *cheſs* exiſt in Bengal; but Sir William had ſeen none of them when he wrote the memoir which we have quoted. He exhibits, however, a deſcription of a very ancient *Indian* game of the ſame kind, but more complex, and in his opinion, more modern than the ſimple cheſs of the *Perſians*. This game is alſo called *Chaturanga*, but more frequently *Chaturaji*, or the *four kings*, ſince it is played by four perſons repreſenting as many princes, two allied armies combating on each ſide. The deſcription is taken from a book called *Bhawiſhya Purân*; in which the form and principal rules of this factitious warfare are thus laid down: "Eight ſquares being marked on all ſides, the *red* army is to be placed to the eaſt, the *green* to the ſouth, the *yellow* to the weſt, and the *black* to the north. Let the *elephant* (ſays the author of the *Purân*) ſtand on the left of the *king*; next to him the *horſe*; then the *boat*; and before them all four *foot-ſoldiers*; but the *boat* muſt be placed in the angle of the board."

"From this paſſage (ſays the preſident) it clearly appears that an army with its four *angâs* muſt be placed on each ſide of the board, ſince an *elephant* could not ſtand, in any other poſition, on the left hand of each *king*; and RADHACANT (a pandit) informed me, that the board conſiſted, like ours, of 64 ſquares, half of them occupied by the forces, and half vacant. He added, that this game is mentioned in the oldeſt law books, and that it was invented by the wife of a king, to amuſe him with an image of war, while his metropolis was beſieged in the ſecond age of the world. A *ſhip* or *boat* is abſurdly ſubſtituted, we ſee, in this complex game for the *rat'h*, or armed *chariot*, which the *Bengaleſe* pronounce *rot'h*, and which the Perſians changed into *rokh*; whence came the *rook* of ſome European nations; as the *vierge* and *fal* of the French are ſuppoſed to be corruptions of *ferz* and *fil*, the *prime miniſter* and *elephant* of the Perſians and Arabs."

As fortune is ſuppoſed to have a great ſhare in deciding the fate of a battle, the uſe of dice is introduced into this game to regulate its moves; for (ſays the Purán) "if *cinque* be thrown, the *king* or a *pawn* muſt be moved; if *quatre*, the *elephant*; if *trois*, the *horſe*; and if *deux*, the *boat*. The *king* paſſes freely on all ſides, but over *one* ſquare only; and with the ſame limitation the *pawn* moves, but he advances ſtraight forward, and kills his enemy through an angle. The *elephant* marches in all directions as far as his driver pleaſes; the *horſe* runs obliquely, traverſing the ſquares; and the *ſhip* goes over two ſquares diagonally." The *elephant*, we find, has the powers of our *queen*, as we are pleaſed to call the *general* or *miniſter* of the Perſians; and the *ſhip* has the motion of the piece, to which we give the unaccountable appellation of *biſhop*, but with a reſtriction which muſt greatly leſſen its value.

In the *Purán* are next exhibited a few general rules and ſuperficial directions for the conduct of the game. Thus, "the *pawns* and the *ſhip* both kill and may be voluntarily killed; while the *king*, the *elephant*, and the *horſe* may ſlay the foe, but muſt not expoſe themſelves to be ſlain. Let each player preſerve his own forces with extreme care, ſecuring his *king* above all, and not ſacrificing a ſuperior to keep an inferior piece." Here (ſays the Preſident) the commentator on the *Purán* obſerves, that the *horſe*, who has the choice of *eight* moves from any central poſition muſt be preferred tot he *ſhip*, which has only the choice of *four*. But the argument would not hold in the common game, where the *biſhop* and *tower* command a whole line, and where a knight is always of leſs value than a tower in action, or the biſhop of that ſide on which the attack is begun. "It is by the overbearing power of the *elephant*, (continues the *Purán*) that the king fights boldly; let the whole army, therefore, be abandoned, in order to ſecure the *elephant*. The king muſt never place one *elephant* before another, unleſs he be compelled by want of room, for he would commit a dangerous fault: and if he can ſlay one of two hoſtile elephants, he muſt deſtroy that on his left hand."

All that remains of the paſſage which was copied for Sir William Jones relates to the ſeveral modes in which a partial ſucceſs or complete victory may be obtained by any one of the four players; for, as in a diſpute between two allies, one of the kings may ſometimes aſſume the command of all the forces, and aim at a ſeparate conqueſt. Firſt, "When any one king has placed himſelf on the ſquare of another king (which advantage is called *ſinhaſana* or the *throne*) he wins a ſtake, which is doubled if he kill the adverſe monarch when he ſeizes his place; and if he can ſeat himſelf on the throne of his ally, he takes the command of the whole army." Secondly, "If he can occupy ſucceſſively the thrones of all the three princes, he obtains the victory, which is named *cheturaji*; and the ſtake is doubled if he kill the laſt of the three, juſt before he takes poſſeſſion of his throne; but if he kill him on his throne, the ſtake is quadrupled. Both in giving the *ſinhaſana* and the *cheturaji* the king muſt be ſupported by the *elephants*, or by all the forces united." Thirdly, "When one player has his own king on the board, but the king of his partner has been taken, he may replace his captive ally, if he can ſeize both the adverſe kings; or, if he cannot effect their capture, he may exchange his king for one of them againſt the general rule, and thus redeem the allied prince, who will ſupply his place." This advantage has the name of *nripacriſhta* or *recovered by the king*. Fourthly, "If a *pawn* can march to any ſquare, on the oppoſite extremity of the board, except that of the king or that of the ſhip, he aſſumes whatever power belonged to that ſquare." Here we find the rule, with a ſlight exception, concerning the advancement of *pawns*, which often occaſions a moſt intereſting ſtruggle at our common cheſs; but it appears that, in the opinion of one ancient writer on the Indian game, this privilege is not allowable when a player has three pawns on the board; but when only one pawn and one ſhip remains, the pawn may advance even to the ſquare of a king or a ſhip, and aſſume the power of either. Fifthly, According to the people of *Lancà*, where the game was invented, "there could be neither victory or defeat, if a king were left on the plain without force; a ſituation which they named *cacacaſht'ha*." Sixthly, "If three ſhips happen to meet, and the fourth ſhip can be brought up to them in the remaining angle, this has the name of *vrihannauca*; and the player of the fourth ſeizes all the others."

The account of this game in the original Sanſcrit is in verſe, and there are two or three couplets ſtill remaining, ſo very dark, either from an error in the manuſcript, or from the antiquity of the language, that Sir William Jones could not underſtand the *Pandit's* explanation of them, and ſuſpects, that even to him, they gave very indiſtinct ideas. It would be eaſy, however, he thinks, if it be judged worth while, to play at the game by the preceding rules, and a little practice would perhaps make the whole intelligible.

CHESTER, a townſhip in Lunenburg co. Nova-Scotia, on Mahone bay, ſettled originally by a few families from New-England. From hence to Windſor is a road, the diſtance of 25 miles.—*Morse.*

CHESTER a ſmall plantation in Lincoln co. Maine, 9 miles from Titcomb. It has 8 or 9 families.—*ib.*

CHESTER, a townſhip in Hampſhire co. Maſſachuſetts, adjoining Weſtfield on the E. and about 20 miles N. W. of Springfield. It contains 177 houſes, and 1119 inhabitants.—*ib.*

CHESTER, a large, pleaſant, and elevated townſhip in Rockingham co. New-Hampſhire. It is 21 miles in length; and on the W. ſide is a pretty large lake, which ſends its waters to Merrimack River. It was incorporated in 1722, and contains 1902 inhabitants, who are chiefly farmers. It is ſituated on the E. ſide of Merrimack River, 14 miles N. W. of Haverhill, as far W. of Exeter, 30 W. by S. of Portſmouth, 6 northerly of Londonderry, and 306 from Philadelphia. From the compact part of this town there is a gentle deſcent to the ſea, which, in a clear day, may be ſeen from thence. It is a poſt town, and contains about 60 houſes and a Congregational church.

Rattleſnake hill, in this townſhip, is a great curioſity: it is half a mile in diameter, of a circular form, and 400 feet high. On the S. ſide, 10 yards from its baſe, is the entrance of a cave, called the Devil's Den, which is a room 15 or 20 feet ſquare, and 4 feet high, floored and circled by a regular rock, from the upper part of which are dependent many excreſcences, nearly in the form and ſize of a pear, which, when approached by a torch, throw out a ſparkling luſtre of almoſt every hue. It is a cold, dreary place, of which many frightful ſtories are told by thoſe who delight in the marvellous.—*ib.*

CHESTER, a townſhip in Windſor co. Vermont, W. of Springfield, and 11 miles W. by S. of Charleſtown, in New-Hampſhire, and contains 981 inhabitants.—*ib.*

CHESTER, a borough and poſt town in Pennſylvania, and the capital of Delaware co. pleaſantly ſituated on the W. ſide of Delaware River near Marcus Hook, and 13 miles N. E. of Wilmington. It contains about 60 houſes, built on a regular plan, a court-houſe and a gaol. From Cheſter to Philadelphia is 20 miles by water, and 15 N. E. by land; here the river is narrowed by iſlands of marſh, which are generally banked, and turned into rich and immenſely valuable meadows. The firſt colonial aſſembly was convened here, the 4th of December, 1682. The place affords genteel inns and good entertainment, and is the reſort of much company from the metropolis, during the ſummer ſeaſon. It was incorporated in December, 1795, and is governed by 2 burgeſſes, a conſtable, a town-clerk, and 3 aſſiſtants; whoſe power is limited to preſerve the peace and order of the place.—*ib.*

CHESTER *Co.* in Pennſylvania, W. of Delaware co. and S. W. of Philadelphia; about 45 miles in length, and 30 in breadth. It contains 33 townſhips, of which Weſt-Cheſter is the ſhire-town, and 27,937 inhabitants, of whom 145 are ſlaves. Iron ore is found in the northern parts, which employs 6 forges. Theſe manufacture about 1000 tons of bar iron annually.—*ib.*

CHESTER *Court-Houſe*, in S. Carolina, 22 miles S. of Pinckney court-houſe, and 58 N. W. of Columbia. A poſt office is kept here.—*ib.*

CHESTER *River*, a navigable water of the eaſtern ſhore of Maryland, which riſes two miles within the line of Delaware ſtate, by two ſources, Cyprus and Andover creeks, which unite at Bridgetown; runs nearly S. weſtward; after paſſing Cheſter it runs S. nearly 3 miles, when it receives S. E. creek, and 15 miles farther, in a S. W. direction, it empties into Cheſapeak bay, at Love point. It forms an iſland at its mouth, and by a channel on the E. ſide of Kent Iſland communicates with Eaſtern bay. It is propoſed to cut a canal, about 11 miles long, from Andover creek, a mile and an half from Bridgetown, to Saliſbury, on Upper Duck creek, which falls into Delaware at Hook iſland.—*ib.*

CHESTER, a ſmall town in Shannandoah co. Virginia, ſituated on the point of land formed by the junction of Allen's or North River and South River which form the Shannandoah; 16 miles S. by W. of Wincheſter. N. lat. 39. 2. W. long. 78. 22.—*ib.*

CHESTER *Co.* in Pinckney diſtrict, S. Carolina, lies in the S. E. corner of the diſtrict, on Wateree River and contains 6866 inhabitants; of whom 5866 are whites, and 938 ſlaves. It ſends two repreſentatives, but no ſenator, to the ſtate legiſlature.—*ib.*

CHESTER, a town in Cumberland co. Virginia, ſituated on the S. W. bank of James River, 15 miles N. of Blandford, and 6 S. of Richmond.—*ib.*

CHESTERFIELD, a townſhip in Hampſhire co. Maſſachuſetts, 14 miles W. of Northampton. It contains 180 houſes, and 1183 inhabitants.

CHESTERFIELD, a townſhip in Cheſhire co. New-Hampſhire, on the E. bank of Connecticut River, having Weſtmoreland N. and Hinſdale S. It was incorporated in 1752, and contains 1905 inhabitants. It lies about 25 miles S. by W. of Charleſtown, and about 90 or 100 W. of Portſmouth. About the year 1730, the garriſon of fort Dummer was alarmed with frequent exploſions and with columns of fire and ſmoke emitted from Weſt river mountain, in this townſhip, and 4 miles diſtant from that fort. The like appearances have been obſerved at various times ſince; particularly one in 1752, was the moſt ſevere of any. There are two places, where the rocks bear marks of having been heated and calcined.—*ib.*

CHESTERFIELD *Co.* in S. Carolina, is in Cheraws diſtrict, on the N. Carolina line. It is about 30 miles long, and 29 broad.—*ib.*

CHESTERFIELD *Co.* in Virginia, is between James and Appamatox rivers. It is about 30 miles long, and 25 broad; and contains 14,214 inhabitants, including 7487 ſlaves.—*ib.*

CHESTERFIELD *Inlet*, on the W. ſide of Hudſon bay, in New South Wales, upwards of 200 miles in length, and from 10 to 30 in breadth—full of iſlands.—*ib.*

CHESTERTOWN, a poſt town and the capital of Kent apprehended, had almoſt happened at Beneventum, when the landlord who entertained Mæcenas and his company was making a ſtrong fire in order to get ſome birds ſooner roaſted.

> '——————— ubi ſedulus hoſpes
> 'Pæne arſit, macros dum turdos verſat in igne;
> 'Nam vaga per veterem dilapſo flamma culinam
> 'Vulcano ſummum properabat lambere tectum †.'

Had there been chimneys in the Roman houſes, Vitruvius certainly would not have failed to deſcribe their conſtruction, which is ſometimes attended with conſiderable difficulties, and which is intimately connected with the regulation of the plan of the whole edifice. He does not, however, ſay a word on this ſubject; neither does Julius Pollux, who has collected with great care the Greek names of every part of a dwelling-houſe; and Grapaldus, who in later times made a collection of the Latin terms, has not given a Latin word expreſſive of a modern chimney."*

Our author admits the derivation of the word *chimney* to be as we have given it in the Encyclopædia; but (ſays he) "*Caminus* ſignified, as far as I have been able to learn, firſt a chemical or metallurgic furnace, in which a crucible was placed for melting and refining metals; ſecondly, a ſmith's forge; and thirdly, a hearth on which portable ſtoves or fire-pans were placed for warming the apartment. In all theſe, however, there appears no trace of a chimney." Herodotus relates (lib. viii. c. 137.), that a king of Libya, when one of his ſervants aſked for his wages, offered him in jeſt the ſun, which at that time ſhone into the houſe through an opening in the roof, under which the fire was perhaps made in the middle of the edifice. If ſuch a hole muſt be called a chimney, our author admits that chimneys were in uſe among the ancients, eſpecially in their kitchens; but it is obvious that ſuch chimneys bore no reſemblance to ours, through which the ſun could not dart his rays upon the floor of any apartment.

"However imperfect may be the information which can be collected from the Greek and Roman authors reſpecting the manner in which the ancients warmed their apartments, it nevertheleſs ſhews that they commonly uſed for that purpoſe a large fire-pan or portable ſtove, in which they kindled wood, and, when the wood was well lighted, carried it into the room, or which they filled with burning coals. When Alexander the Great was entertained by a friend in winter, as the weather was cold and raw, a ſmall fire baſon was brought into the apartment to warm it. The prince obſerving the ſize of the veſſel, and that it contained only a few coals, deſired his hoſt, in a jeering manner, to bring more wood or frankincenſe; giving him thus to underſtand that the fire was fitter for burning perfumes than to produce heat. Anacharſis, the Scythian philoſopher, though diſpleaſed with many of the Grecian cuſtoms, praiſed the Greeks, however, becauſe they ſhut out the ſmoke and brought only fire into their houſes.* We are informed by Lampridius, that the extravagant Heliogabulus cauſed to be burned in theſe ſtoves, inſtead of wood, Indian ſpiceries and coſtly perfumes†. It is alſo worthy of notice, that coals were found in ſome of the apartments of Herculaneum, as we are told by Winklemann, but neither ſtoves nor chimneys."

It is well known to every ſcholar, that the uſeful arts of life were invented in the eaſt, and that the cuſtoms, manners, and furniture of eaſtern nations, have remained from time immemorial almoſt unchanged. In Perſia, which the late Sir William Jones ſeems to have conſidered as the original country of mankind, the methods employed by the inhabitants for warming themſelves have a great reſemblance to thoſe employed by the ancient Greeks and Romans for the ſame purpoſe. According to De la Valle, the Perſians make fires in their apartments, not in chimneys as we do, but in ſtoves in the earth, which they call *tennor*. "Theſe ſtoves conſiſt of a ſquare or round hole, two ſpans or a little more in depth, and in ſhape not unlike an Italian caſk. That this hole may throw out heat ſooner, and with more ſtrength, there is placed in it an iron veſſel of the ſame ſize, which is either filled with burning coals, or a fire of wood and other inflammable ſubſtances is made in it. When this is done, they place over the hole or ſtove a wooden top, like a ſmall low table, and ſpread above it a large coverlet quilted with cotton, which hangs down on all ſides to the floor. This covering condenſes the heat, and cauſes it to warm the whole apartment. The people who eat or converſe there, and ſome who ſleep in it, lie down on the floor above the carpet, and lean, with their ſhoulders againſt the wall, on ſquare cuſhions, upon which they ſometimes alſo ſit; for the *tennor* is conſtructed in a place equally diſtant from the walls on both ſides. Thoſe who are not very cold only put their feet under the table or covering; but thoſe who require more heat can put their hands under it, or creep under it altogether. By theſe means the ſtove diffuſes over the whole body, without cauſing uneaſineſs to the head, ſo penetrating and agreeable a warmth, that I never in winter experienced any thing more pleaſant. Thoſe, however, who require leſs heat let the coverlet hang down on their ſide to the floor, and enjoy without any inconvenience from the ſtove the moderately heated air of the apartment. They have a method alſo of ſtirring up or blowing the fire when neceſſary, by means of a ſmall pipe united with the tennor or ſtove under the earth, and made to project above the floor as high as one chooſes; ſo that the wind, when a perſon blows into it, becauſe it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occaſion to uſe this ſtove, both holes are cloſed up, that is to ſay, the mouth of the ſtove and that of the pipe which conveys the air to it, by a flat ſtone made for that purpoſe. Scarcely any appearance of them is then to be perceived, nor do they occaſion inconvenience, eſpecially in a country where it is always cuſtomary to cover the floor with a carpet, and where the walls are plaſtered. In many parts theſe ovens are uſed to cook victuals, by placing kettles over them. They are employed alſo to bake bread; and for this purpoſe they are covered with a large broad metal plate, on which the cake is laid; but if the bread is thick and requires more heat, it is put into the ſtove itſelf."

Our learned author having proved, to our entire ſatisfaction, that chimneys, ſuch as we have now in every comfortable room, were unknown to the moſt poliſhed nations of antiquity, ſets himſelf to inquire into the era of their invention; and the oldeſt account of them which he finds is an inſcription at Venice, which relates, that in the year 1347 a great many chimneys were

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† *Horat.* lib. i. ſat. 5.

* *Franciſci Marii Grapaldi de partibus ædium libri.*

* *Plutarch. Sympoſ.* lib. vi. 7. p. 692.

† *Æl. Lamprid. Vita Heliogab.* cap. 31.

immediately behind the mantle. It is the wall which forms the entrance from below into the throat of the chimney in front, or towards the room. It is oppoſite to the upper extremity of the back of the open fire-place, and parallel to it: in ſhort, it may be ſaid to be the back part of the mantle itſelf.—In the figures 1. and 2. it is marked by the letter *d*. The width of the throat of the chimney (*d e* fig. 1. and *d i* fig. 2.) is taken from the breaſt of the chimney to the back, and its length is taken at right angles to its width, or in a line parallel to the mantle (*a* fig. 1. and 2.)

The bringing forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminiſhing of the throat of the chimney, being two objects principally had in view in the alterations in fire-places propoſed by the Count, it is evident that both theſe may be attained merely by bringing forward the back of the chimney. The only queſtion therefore is, How far it ſhould be brought forward? The anſwer is ſhort, and eaſy to be underſtood; bring it forward as far as poſſible, without diminiſhing too much the paſſage which muſt be left for the ſmoke. Now as this paſſage, which in its narroweſt part he calls *the throat of the chimney*, ought, for reaſons which have been already explained, to be immediately, or perpendicularly over the fire, it is evident that the back of the chimney muſt always be built perfectly upright. To determine, therefore, the place for the new back, or how far preciſely it ought to be brought forward, nothing more is neceſſary than to aſcertain how wide the throat of the chimney ought to be left, or what ſpace muſt be left between the top of the breaſt of the chimney where the upright canal of the chimney begins, and the new back of the fire-place carried up perpendicularly to that height.

Numerous experiments have convinced the Count, that, all circumſtances being well conſidered, and the advantages and diſadvantages compared and balanced, *four inches* is the beſt width that can be given to the throat of a chimney, whether the fire-place be deſtined to burn wood, coals, turf, or any other fuel. In very large halls where great fires are kept up, it may ſometimes, though very rarely, be proper to increaſe this width to four inches and a half, or even to five inches.

The next thing to be conſidered is the width which it will be proper to give to the back of the chimney; and, in moſt caſes, this ſhould be *one-third* of the width of the opening of the fire-place in front. It is not indeed abſolutely neceſſary to conform with rigour to this deciſion, nor is it always poſſible; but it ſhould invariably be conformed to as far as circumſtances will permit. Where a chimney, ſays the Count, is deſigned for warming a room of a middling ſize, and where the thickneſs of the wall of the chimney in front, meaſured from the front of the mantle to the breaſt of the chimney, is nine inches, I ſhould ſet off four inches more for the width of the throat of the chimney, which, ſuppoſing the back of the chimney to be built upright, as it always ought to be, will give thirteen inches for the depth of the fire-place, meaſured upon the hearth, from the opening of the fire-place in front to the back. In this caſe, thirteen inches would be a good ſize for the width of the back; and three times thirteen inches, or 39 inches, for the width of the opening of the fire-place in front; and the angle made by the back of the fire-place and the ſides of it, or covings, would be juſt 135 degrees, which is the beſt poſition they can have for throwing heat into the room. This poſition, indeed, it may ſometimes be impoſſible to attain in altering chimneys already built; but a deviation from it of two or three degrees will be of no great conſequence; for the points of by much the greateſt importance in altering fire-places upon the principles here recommended, are the bringing forward the back to its proper place, and making it of the proper width.

Proviſion, however, muſt be made for the paſſage of the chimney-ſweeper up the chimney; and this may eaſily be done in the following manner: In building up the new back of the fire-place; when this wall (which need never be more than the width of a ſingle brick in thickneſs) is brought up ſo high that there remains no more than about ten or eleven inches between what is then the top of it and the inſide of the mantle, or lower extremity of the breaſt of the chimney, an opening or door-way, eleven or twelve inches wide, muſt be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be neceſſary to carry up the back, will make the opening abundantly ſufficient to let the chimney-ſweeper paſs. When the fire place is finiſhed, this door-way is to be cloſed by a tile or fit piece of ſtone placed in it without mortar, and by means of a rabbit made in the brick-work, confined in its place in ſuch a manner as that it may be eaſily removed when the chimney is to be ſwept, and reſtored to its place when that work is over. Of this contrivance the reader will be able to form a clear conception from fig. 2. which repreſents the ſection of a chimney after it has been properly altered from what is exhibited in fig. 1. In this improved chimney *k l* is the new back of the fire place; *l i* the tile or ſtone which cloſes the door-way for the chimney-ſweeper; *d i* the throat of the chimney narrowed to four inches; *a* the mantle, and *b* the ſtone placed under the mantle, ſuppoſed to have been too high, in order to diminiſh the height of the opening of the fire-place in front.

It has been obſerved above, that the new back, which it will always be found neceſſary to build in order to bring the fire ſufficiently forward, in altering a chimney conſtructed on the common principles, need never be thicker than the width of a common brick. The ſame may be ſaid of the thickneſs neceſſary to be given to the new ſides or covings of the chimney; or if the new back and covings are conſtructed of ſtone, one inch and three quarters, or two inches in thickneſs, will be ſufficient. Care ſhould be taken in building up theſe new walls to unite the back to the covings in a ſolid manner.

Whether the new back and covings are conſtructed of ſtone or built of bricks, the ſpace between them and the old back and covings of the chimney ought to be filled up to give greater ſolidity to the ſtructure. This may be done with looſe rubbiſh, or pieces of broken bricks or ſtones, provided the work be ſtrengthened by a few layers or courſes of bricks laid in mortar; but it will be indiſpenſably neceſſary to finiſh the work where theſe new walls end, that is to ſay, at the top of the throat of the chimney, where it ends abruptly in the open canal of the chimney, by a horizontal courſe of bricks well ſecured with mortar. This courſe of bricks will be upon a level with the top of the door-way left for the chimney-ſweeper; and the void behind the doorway muſt be covered with a horizontal ſtone or tile, to be removed at the ſame time the door is removed, and for the ſame purpoſe.

From theſe deſcriptions it is clear, that where the throat of the chimney has an end, that is to ſay, where it enters into the lower part of the open canal of the chimney, *there* the three walls which form the two covings and the back of the fire-place all end abruptly. It is of much importance that they ſhould end in this manner; for were they to be ſloped outward, and raiſed in ſuch a manner as to ſwell out the upper extremity of the throat of the chimney in the form of a trumpet, and increaſe it by degrees to the ſize of the canal of the chimney, this manner of uniting the lower extremity of the canal of the chimney with the throat would tend to aſſiſt the winds, which may attempt to blow down the chimney, in forcing their way through the throat, and throwing the ſmoke backward into the room; but when the throat of the chimney ends abruptly, and the ends of the new walls form a flat horizontal ſurface, it will be much more difficult for any wind from above to find and force its way through the narrow paſſage of the throat of the chimney.

As the two walls which form the new covings of the chimney are not parallel to each other, but inclined, preſenting an oblique ſurface towards the front of the chimney, and as they are built perfectly upright, and quite flat, from the hearth to the top of the throat, where they end, it is evident that an horizontal ſection of the throat will not be an oblong ſquare; but its deviation from that form is a matter of no conſequence; and no attempts ſhould ever be made, by twiſting the covings above where they approach the breaſt of the chimney, to bring it to that form. All twiſts, bends, prominences, excavations, and other irregularities of form in the covings of a chimney, never fail to produce eddies in the current of air which is continually paſſing into, and through, an open fire-place in which a fire is burning; and all ſuch eddies diſturb either the fire or the aſcending current of ſmoke, or both; and not unfrequently cauſe the ſmoke to be thrown back into the room. Hence it appears, that the covings of chimneys ſhould never be made circular, or in the form of any other curve, but always quite flat.

For the ſame reaſon, that is to ſay, to prevent eddies, the breaſt of the chimney, which forms that ſide of the throat that is in front or neareſt to the room, ſhould be neatly cleaned off, and its ſurface made quite regular and ſmooth. This may be eaſily done by covering it with a coat of plaſter, which may be made thicker or thinner in different parts, as may be neceſſary in order to bring the breaſt of the chimney to be of the proper form.

With regard to the form of the breaſt of a chimney, this is a matter of very great importance, and which ought always to be particularly attended to. The worſt form it can have is that of a vertical plane or upright flat; and next to this the worſt form is an inclined plane. Both theſe forms cauſe the current of warm air from the room, which will, in ſpite of every precaution, ſometimes find its way into the chimney, to croſs upon the current of ſmoke which riſes from the fire in a manner moſt likely to embarraſs it in its aſcent, and drive it back.

The current of air which paſſing under the mantle, gets into the chimney, ſhould be made *gradually to bend its courſe upwards*; by which means it will unite *quietly* with the aſcending current of ſmoke, and will be leſs likely to check it, or force it back into the room. Now this may be effected with the greateſt eaſe and certainty, merely by *rounding off* the breaſt of the chimney or back part of the mantle, inſtead of leaving it flat or full of holes and corners; and this of courſe ought always to be done.

Having thus aſcertained the form and poſition of the new covings, the ingenious author next turns his attention to the height to which they ſhould be carried. This will depend not only on the height of the mantle, but alſo, and more eſpecially, on the height of the breaſt of the chimney, or of that part of the chimney where the breaſt ends and the upright canal begins.—The back and covings muſt riſe a few inches, five or ſix for inſtance, higher than this part, otherwiſe the throat of the chimney will not be properly formed; but no advantage would be gained by carrying them higher.

One important circumſtance reſpecting chimney fire-places ſtill remains to be conſidered; and that is the grate. In placing the grate, the thing principally to be attended to is, to make the back of it coincide with the back of the fire-place. But as many of the grates now in common uſe will be found to be too large, when the fire-places are altered and improved, it will be neceſſary to diminiſh their capacities by filling them up at the back and ſides with pieces of fire-ſtone. When this is done, it is the front of the flat piece of fire-ſtone which is made to form a new back to the grate, which muſt be made to coincide with, and make part of the back of the fire-place.—But in diminiſhing the capacities of grates with pieces of fire-ſtone, care muſt be taken not to make them *too narrow*.

The proper width for grates deſtined for rooms of a middling ſize will be from ſix to eight inches, and their length may be diminiſhed more or leſs according as the room is heated with more or leſs difficulty, or as the weather is more or leſs ſevere.—But where the width of a grate is not more than five inches it will be very difficult to prevent the fire from going out.

It frequently happens that the iron backs of grates are not vertical, or upright, but inclined backwards.—When theſe grates are ſo much too wide as to render it neceſſary to fill them up behind with fire-ſtone, the inclination of the back will be of little conſequence; for by making the piece of ſtone with which the width of the grate is to be diminiſhed in the form of a wedge, or thicker above than below, the front of this ſtone, which in effect will become the back of the grate, may be made perfectly vertical; and the iron back of the grate being hid in the ſolid work of the back of the fire-place, will produce no effect whatever; but if the grate be already ſo narrow as not to admit of any diminution of its width, in that caſe it will be beſt to take away the iron back of the grate entirely, and fixing the grate firmly in the brick-work, cauſe the back of the fire-place to ſerve as a back to the grate.

Where grates, which are deſigned for rooms of a middling ſize, are longer than 14 or 15 inches, it will always be beſt, not merely to diminiſh their lengths, by filling them up at their two ends with fire-ſtone, but,

forming

mney ‖ ina.

guous flues we know to be leſs injured by this method of ſweeping, when cautiouſly gone about, than by ſending boys up the chimneys.

On the 4th of July 1796, letters patent were granted to Daniel Davis, of the pariſh of St Giles Middleſex, for his invention of a machine, by which he propoſes to ſweep and cleanſe chimneys, and extinguiſh chimneys on fire, without any perſon going up the ſame, as is now the practice. The machine conſiſts of an apparatus of rack work, of various lengths, which, by means of a hand-turn, is made to aſcend the chimney. The lengths of the rack-work are joined together by means of mortiſes and tenons, with a ſpring which holds them faſt. In each length is a joint, by which the rack-work will accommodate itſelf to angles or turns in the flues. To the firſt or uppermoſt length is affixed a bruſh of hair, or wire, or ſpunge, or other elaſtic ſubſtance, as the occaſion may require.

This invention is doubtleſs well calculated to anſwer the purpoſe intended, and may perhaps be the means of diminiſhing the number of thoſe objects of miſery, the unfortunate chimney-ſweepers.

CHINA is an empire of ſuch antiquity and extent, the laws and cuſtoms of the people are ſo ſingular, and the populouſneſs of the country ſo very great—that it has attracted much of the attention of Europeans ever ſince it was viſited in the 13th century by Marco Paulo the Venetian traveller. Of ſuch a country it would be unpardonable not to give ſome account in a work of this nature; but we have not, in truth, much to add to what has been ſaid of China and the Chineſe in the Encyclopædia. Since the article CHINA in that work was publiſhed, the court of Pekin has indeed been viſited by an embaſſy from Great Britain, and the origin of the people, as well as the antiquity of their empire, has been inveſtigated by Sir William Jones with his uſual diligence; but from his memoir, publiſhed in the ſecond volume of the Aſiatic Reſearches, and from Sir George Staunton's account of the embaſſy, there is not much to be extracted which would be either amuſing or inſtructive to our readers.

China.

We have already obſerved, from Groſier and others, that the Chineſe not only lay claim to the higheſt antiquity, but even contend that their firſt emperor was the firſt man. Both theſe poſitions are controverted by Sir William Jones, who, though he allows the Chineſe empire to be very ancient when compared with the oldeſt European ſtate, is yet decidedly of opinion that it was not founded at an earlier period than the 12th century before the Chriſtian era; and that the people, ſo far from being aborigines, are a mixed race of Tartars and Hindoos. He begins his inveſtigation with aſking, "Whence came the ſingular people who long had governed China, before they were conquered by the Tartars? On this problem (ſays he‡) four opinions have been advanced, and all rather peremptorily aſſerted than ſupported by argument and evidence. By a few writers it has been urged, that the *Chineſe* are an original race, who have dwelled for ages, if not from eternity, in the land which they now poſſeſs. By others, and chiefly by the miſſionaries, it is inſiſted that they ſprung from the ſame ſtock with the *Hebrews* and the *Arabs*. A third aſſertion is that of the Arabs themſelves, and of M. PAUW, who hold it indubitable, that they were originally *Tartars*, deſcending in wild clans from the ſteeps of Imaus: And a fourth, at leaſt as dogmatically pronounced as any of the preceding, is that of the *Brahmans*, who decide, without allowing any appeal from their deciſion, that the *Chinas* (for ſo they are named in *Sanſcrit)* were Hindoos of the military caſt, who, abandoning the privileges of their tribe, rambled in different bodies to the north-eaſt of *Bengal;* and forgetting by degrees the rites and the religion of their anceſtors, eſtabliſhed ſeparate principalities, which were afterwards united in the plains and valleys which are now poſſeſſed by them."

Of theſe opinions, Sir William having very completely demoliſhed the firſt three, proceeds to eſtabliſh the fourth, which he conſiders as intereſting as well as new in Europe. In the Sanſcrit inſtitutes of civil and religious duties, revealed, as the Hindoos believe, by MENU the ſon of Brahma, we find (ſays he) the following curious paſſage: 'Many families of the military claſs, having gradually abandoned the ordinances of the *Veda*, and the company of *Brahmans*, lived in a ſtate of degradation; as the people of *Pundraca* and *Odra*, thoſe of *Dravira* and *Camboja*, the *Yavanas* and *Sacas*, the *Paradas* and *Pahlavas*, the CHINAS, and ſome other nations.' A full comment on this text (continues the preſident) would be ſuperfluous; but ſince the teſtimony of the Indian author, who, though not a divine perſonage, was certainly a very ancient lawyer, moraliſt, and hiſtorian, is direct and poſitive, diſintereſted and unſuſpected, it would decide the queſtion before us if we could be ſure that the word *China* ſignifies a *Chineſe*." Of this fact Sir William Jones took the very beſt methods to be ſatisfied. He conſulted a number of Pandits ſeparately, who all aſſured him that the word *China* has no other ſignification in *Sanſcrit;* that the *Chinas* of MENU ſettled in a fine country to the north-eaſt of *Gaur*, and to the eaſt of *Camarup* and *Napal;* that they had long been, and ſtill are, famed as ingenious artificers; and that they (the Pandits) had themſelves ſeen old Chineſe idols, which bore a manifeſt relation to the primitive religion of India. He then laid before one of the beſt informed *Pandits* a map of Aſia; and when his own country was pointed out to him, the *Pandit* immediately placed his finger on the north-weſtern provinces of China, as the place where he ſaid the *Chinas* of MENU firſt eſtabliſhed themſelves.

In the opinion of Sir William Jones, this is complete evidence that the Chineſe are deſcended from an Indian race; but he does not believe that the Chineſe empire, as we now call it, was formed when the laws of MENU were collected; and for his calling this fact in queſtion, he offers reaſons, which to us are perfectly ſatisfactory. By a diligent and accurate compariſon of ancient Sanſcrit writings, he has been able to fix the period of the compilation of thoſe laws at between 1000 and 1500 years before Chriſt; but by the evidence of Confucius himſelf, he proves, that if the Chineſe empire was formed, it could be only in its cradle in the 12th century before our era. In the ſecond part of the work, intitled *Lún Yú*, Confucius declares, that "although he, like other men, could relate, as mere leſſons of morality, the hiſtories of the firſt and ſecond imperial houſes, yet, *for want of evidence*, he could give no certain account of them." Now, ſays Sir William, if the Chineſe themſelves do not pretend that any hiſtorical monument exiſted in the age of Confucius preceding the

‡ *Aſiatic Re-arches*, ol. ii. ıem. 25.

the riſe of their third dynaſty, about 1100 years before the Chriſtian epoch, we may juſtly conclude, that their empire was then in its infancy, and did not grow to maturity till ſome ages afterwards. Nay, he is inclined to bring its origin ſtill lower down. "It was not, ſays he, till the eighth century before the birth of our Saviour, that a ſmall kingdom was erected in the province of *Shen-ſi*, the capital of which ſtood nearly in the 35th degree of northern latitude, and about five degrees to the weſt of *Si-gan*. That country and its metropolis were both called *Chin;* and the dominion of its princes was gradually extended to the eaſt and weſt. The territory of *Chin*, ſo called by the old Hindoos, by the Perſians, and by the Chineſe, gave its name to a race of emperors, whoſe tyranny made their memory ſo unpopular, that the modern inhabitants of China hold the word in abhorrence, and ſpeak of themſelves as the people of a milder and more virtuous dynaſty: but it is highly probable, that the whole nation deſcended from the *Chinas* of Menu, and mixing with the *Tartars*, by whom the plains of *Honan* and the more ſouthern provinces were thinly inhabited, formed by degrees the race of men whom we now ſee in poſſeſſion of the nobleſt empire in Aſia."

In ſupport of this opinion, which the accompliſhed author offers as the reſult of long and anxious inquiries, he obſerves, that the Chineſe have no ancient monuments from which their origin can be traced, even by plauſible conjecture; that their ſciences are wholly *exotic;* that their mechanic arts have nothing in them which any ſet of men, in a country ſo highly favoured by nature, might not have diſcovered and improved; that their philoſophy ſeems yet in ſo rude a ſtate as hardly to deſerve the appellation; and that their popular religion was imported from *India* in an age comparatively modern. He then inſtitutes a compariſon between the mythology of the Chineſe and that of the Hindoos; of which the reſult is, that the former people had an *ancient* ſyſtem of ceremonies and ſuperſtitions which has an apparent affinity with ſome parts of the oldeſt Indian worſhip. "They believed in the agency of genii or tutelary ſpirits, preſiding over the ſtars and the clouds; over lakes and rivers, mountains, valleys, and woods; over certain regions and towns; over all the elements, of which, like the Hindoos, they reckoned five; and particularly over *fire*, the moſt brilliant of them. To thoſe deities they offered victims on high places. And the following paſſage from one of their ſacred books, ſays Sir William, is very much in the ſtyle of the Brahmans: 'Even they who perform a ſacrifice with due reverence, cannot perfectly aſſure themſelves that the divine ſpirits accept their oblations; and far leſs can they, who adore the gods with languor and oſcitancy, clearly perceive their ſacred illapſes.' Theſe (continues the preſident) are imperfect traces indeed, but they *are* traces of an affinity between the religion of Menu and that of the *Chinas*, whom he names among the apoſtates from it; and beſides them, we diſcover many other very ſingular marks of relation between the Chineſe and the old Hindoos.

"This relation (he thinks) appears in the remarkable period of 432,000, and the cycle of 60 years; in the predilection for the myſtical number *nine;* in many ſimilar faſts and great feſtivals, eſpecially at the ſolſtices and equinoxes; in the obſequies, conſiſting of rice and fruits offered to the manes of their anceſtors; in the dread of dying childleſs, leſt ſuch offerings ſhould be intermitted; and perhaps in their common abhorrence of *red* objects, which the Indians carried ſo far, that Menu himſelf, where he allows a *Brahman* to trade, if he cannot otherwiſe ſupport life, abſolutely forbids his trading in any ſort of *red* cloths, whether linen, or woollen, or made of woven bark. In a word, ſays Sir William Jones, all the circumſtances which have been mentioned ſeem to prove (as far as ſuch a queſtion admits proof), that the Chineſe and Hindoos were originally the ſame people; but having been ſeparated near 4000 years, they have retained few ſtrong features of their ancient conſanguinity, eſpecially as the Hindoos have preſerved their old language and ritual, while the Chineſe very ſoon loſt both; and the Hindoos have conſtantly intermarried among themſelves, while the Chineſe, by a mixture of Tartarian blood from the time of their firſt eſtabliſhment, have at length formed a race diſtinct in appearance both from Indians and Tartars."

Sir George Staunton, who accompanied the Earl of Macartney on his embaſſy to the emperor of China, does not indeed directly controvert this reaſoning; but overlooking it altogether, gives to the Chineſe a much higher antiquity than Sir William Jones is inclined to allow them. Taking it for granted that their *cycle* is their own, and that it is not the offſpring of aſtronomical ſcience, but of repeated obſervations, he ſeems to give implicit credit to thoſe annals of the empire which almoſt every other writer has conſidered as fabulous.

"Next to the ſtudies which teach the economy of life, the Chineſe (ſays he) value moſt the hiſtory of the events of their own country, which is, to them, the globe; and of the celeſtial movements which they had an opportunity of obſerving at the ſame time." In regard to the former, he tells us, that "from about *three* centuries before the Chriſtian era the tranſactions of the Chineſe empire have been regularly, and without any intervening chaſm, recorded both in official documents and by private contemporary writers. Nowhere had hiſtory become ſo much an object of public attention, and nowhere more the occupation of learned individuals. Every conſiderable town throughout the empire was a kind of univerſity, in which degrees were conferred on the proficient in the hiſtory and government of the ſtate. Hiſtorical works were multiplied throughout. The accounts of *recent* events were expoſed to the correction of the witneſſes of the facts, and compilations of former tranſactions to the criticiſms of rival writers." In regard to the latter, the movements of the heavenly bodies, he thinks that in no country are there ſtronger inducements or better opportunities to watch them than in China; and hence he infers, that the cycle of ſixty years is of Chineſe formation. "In a climate (ſays he) favourable to aſtronomy, the balance of hours beyond the number of days during which the ſun appeared to return oppoſite to, and to obſcure, or to mix among the ſame fixed ſtars, might be aſcertained in a ſhort time; and occaſioned the addition of a day to every fourth year, in order to maintain regularity in the computation of time, in regard to the return of the ſeaſons; but many ages muſt have paſt before a period could have been diſcovered, in which the unequal returns of the ſun and moon were ſo accurately adjuſted, that at its termination

CHIMNEY, PLATE XX.

Fig. 3.

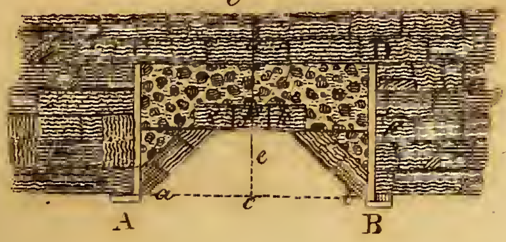


Fig. 5.

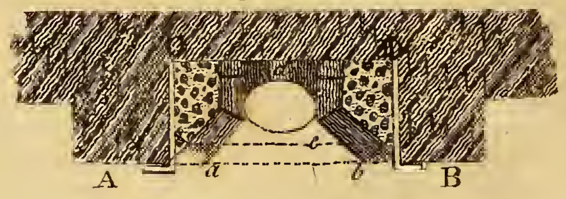


Fig. 8.

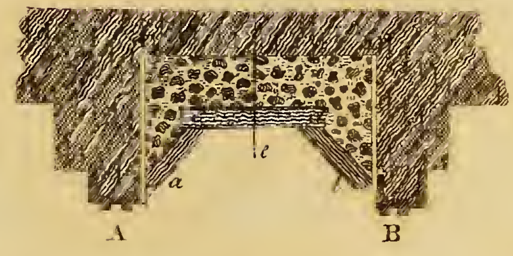
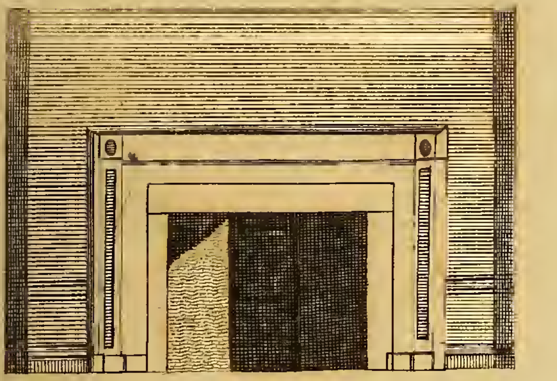


Fig. 4.



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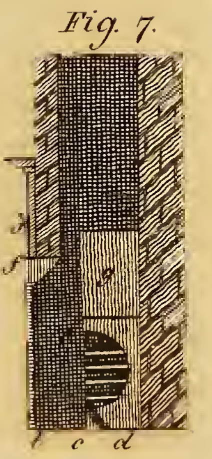

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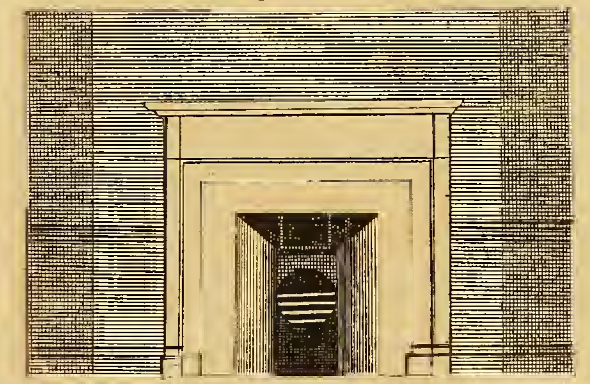


Scale 1 2 3 4 5 *of Feet*

CRANE

Fig. 1

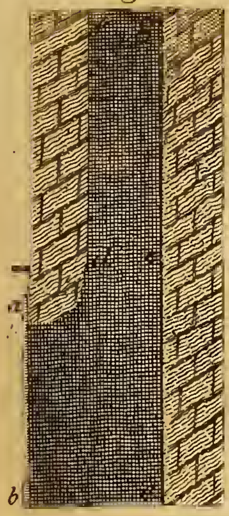


Fig. 1.

Fig. 2.

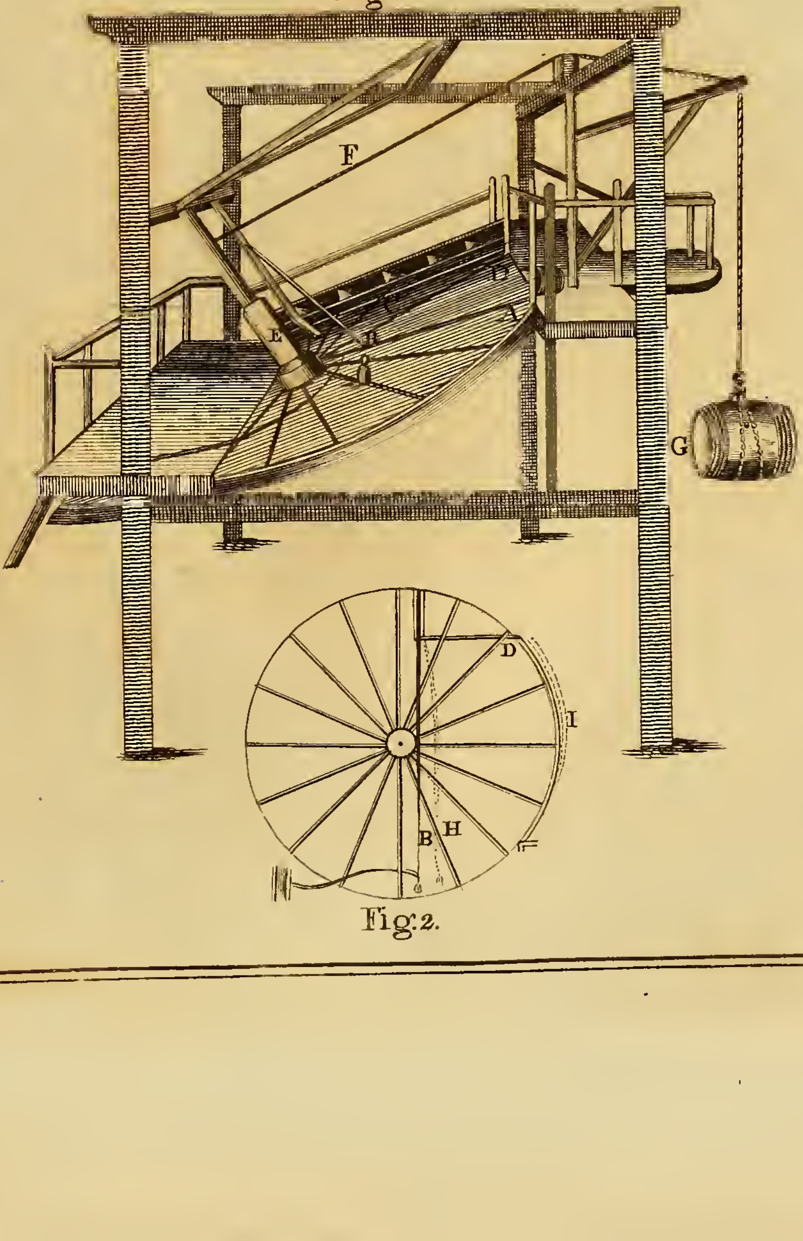
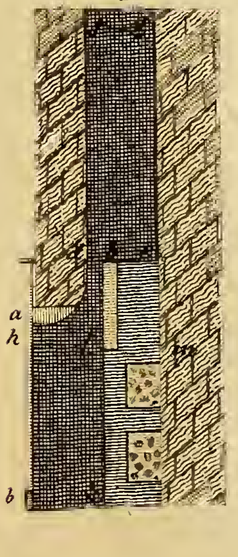


Fig. 2.



B. Jones sc.

tion the new and full moons ſhould return, not only to the ſame day, but within an hour and a half of the time they had happened, when the period commenced. The knowledge of ſuch a period or cycle could be obtained only by a multiplicity of careful and accurate obſervations. Many revolutions of thoſe great luminaries muſt have been completed, and numberleſs conjunctions have paſt over, before their returns could be aſcertained to happen in the ſame day, at the end of nineteen years. The ſmall difference of time between the returning periods of this cycle, was partly leſſened by the intervention of another of 60 years, or of 720 revolutions of the moon, which, with the ſettled intercalation of 22 lunations, were at firſt ſuppoſed to bring a perfect coincidence of the relative poſitions of the ſun and moon: but even according to this period, every new year was made conſtantly to recede, in a very ſmall degree, which the Chineſe corrected afterwards from time to time. This cycle anſwered a double purpoſe, one as an era for chronological reckoning, and the other as a regulating period for a luni-ſolar year. Each year of the cycle is diſtinguiſhed by the union of two characters, taken from ſuch an arrangement of an unequal number of words placed in oppoſite columns, that the ſame two characters cannot be found again together for ſixty years. The firſt column contains a ſeries of ten words, the other twelve; which laſt are, in fact, the ſame that denote the twelve hours or diviſions of the day, each being double the European hour. The firſt word or character of the firſt ſeries or column of ten words, joined to the firſt word of the ſecond ſeries or column of twelve, marks the firſt year of the cycle; and ſo on until the firſt ſeries is exhauſted, when the eleventh word of the ſecond ſeries, combined with the firſt of the firſt ſeries, marks the eleventh year of the cycle; and the twelfth or laſt of the ſecond ſeries, joined with the ſecond of the firſt ſeries, ſerves for denoting the twelfth year. The third of the firſt ſeries becomes united in regular progreſſion with the firſt of the ſecond ſeries, to mark the thirteenth year; and proceeding by this rule, the firſt character in the firſt and in the ſecond ſeries cannot come again together for ſixty years, or until the firſt year of the ſecond cycle. The Chriſtian year 1797 anſwers to the 54th year of the 68th Chineſe cycle, which aſcertains its commencement to have been 2277 years before the birth of Chriſt; unleſs it be ſuppoſed that the official records and public annals of the empire, which bear teſtimony to it, ſhould all be falſified, and that the cycle when firſt eſtabliſhed ſhould have been antedated; which is indeed as little probable as that the period, for example, of the Olympiads ſhould be aſſerted to have commenced many ages prior to the firſt Olympic games."

This is a very poſitive deciſion againſt the opinion of a man whoſe talents and knowledge of oriental learning were ſuch as to give to his opinions on ſuch ſubjects the greateſt weight. If the ſtatements and reaſonings of Sir George Staunton be accurate, the Chineſe empire muſt have ſubſiſted at leaſt 3000 years before the Chriſtian era; for he ſays expreſsly, that *many ages* muſt have elapſed before the commencement of that cycle, which, according to him, commenced 2277 years before the birth of Chriſt. But ſurely Confucius was as well acquainted with the ancient annals of his own country, and the credibility which is due to them, as any man of the preſent age, whether Chineſe or European; and we have ſeen, that he conſidered none of them as authentic which relate events previous to the 11th century before our era. Even this is by much too early a period at which to rely upon them with implicit confidence, if it be true, as Sir George informs us, that the tranſactions of the empire have been regularly recorded only from about *three* centuries before the birth of Chriſt. With reſpect to the cycle, there is every probability that it was derived from India, where we know that aſtronomy has been cultivated as a ſcience from time immemorial, and where, we have ſhewn in another place, that the commencement of the cycle was actually antedated (ſee PHILOSOPHY, n° 9. *Encycl.*) We have therefore no heſitation in preferring Sir William Jones's opinion of the origin of the Chineſe empire to Sir George Staunton's; not merely becauſe we believe the former of theſe gentlemen to have been more converſant than the latter with Chineſe literature, but becauſe we think his reaſoning more conſiſtent with itſelf, and his concluſion more conſonant to that outline of chronology, which, as he obſerves, has been ſo correctly traced for the laſt 2,000 years, that we muſt be hardy ſceptics to call it in queſtion.

There is another point very nearly related indeed to this about which theſe two learned men likewiſe differ. Sir George Staunton informs us, that "no accounts of a general deluge are mentioned in Chineſe hiſtory." Sir William Jones, on the other hand, in the diſcourſe already quoted, ſays, "I may aſſure you, after full inquiry and conſideration, that the Chineſe, like the Hindoos, believe this earth to have been wholly covered with water, which, in works of undiſputed authenticity, they deſcribe as *flowing abundantly, then ſubſiding, and ſeparating the higher from the lower age of mankind.*" To which of theſe authors ſhall we give credit? The high antiquity which Sir George Staunton aſſigns to the Chineſe empire rendered it neceſſary for the perſons from whom he drew his information to get quit by any means of an univerſal deluge. The ſyſtem of Sir William Jones left him at liberty to admit or reject that event according to evidence; and in addition to the authentic records to which he appeals, he quotes a mythological fable of the Chineſe, and another of the Hindoos, which, though he lays not upon them any great ſtreſs, appear to us, when compared together, not only to corroborate his opinion reſpecting the deſcent of the Chineſe, but likewiſe to ſhew that both they and the Hindoos have preſerved a traditionary account of the deluge very ſimilar to that which is given by Moſes. The Chineſe fable is this: "The mother of FO-HI was the *daughter of Heaven*, ſurnamed *Flower-loving*; and as the nymph was walking alone on the brink of a river with a ſimilar name, ſhe found herſelf on a ſudden encircled with a *rainbow*; ſoon after which ſhe became pregnant, and at the end of twelve years was delivered of a ſon, radiant as herſelf, who among other titles, had that of *Sui*, or *the Star of the Year*." In the mythological ſyſtem of the Hindoos, "the nymph ROHINI, who preſides over the fourth lunar manſion, was the favorite miſtreſs of SOMA or the Moon, among whoſe numerous epithets we find *Cumudanúyaca*, or delighting in a ſpecies of *water-flower* that bloſſoms at night. The offspring of ROHINI and SOMA was BUDHA, regent of a planet; and he married ILA, whoſe father cyclopædia containing explanations of the ideas themſelves repreſented by ſuch hieroglyphics. In ſuch ſenſe only can the acquiſition of Chineſe words be juſtly ſaid to engroſs moſt of the time of men of learning among them. The knowledge of the ſciences of the Chineſe, however imperfect, and of their moſt extenſive literature, is certainly ſufficient to occupy the life of man. Enough, however, of the language is imperceptibly acquired by every native, and may, with diligence, be acquired by foreigners for the ordinary concerns of life; and further improvements muſt depend on capacity and opportunity."

Next to the ſingular ſtructure of the oral and written language of the Chineſe, there is perhaps nothing in their hiſtory more ſurpriſing to a native of Europe than the number of the people, and the means by which they contrive to procure ſubſiſtence, without foreign trade, in a country ſo crouded, and at the ſame time not everywhere of a fertile ſoil. In the Encyclopædia, the population of this vaſt empire is ſtated, from M. Groſier, at 200 millions: but great as this is, when compared with the population of every other extenſive country, it appears to be far ſhort of the truth. Sir George Staunton has publiſhed a ſtatement, taken from one of the public offices in the capital, and given by a great and reſpectable manderin to Lord Macartney, in which it is ſhewn that China Proper contains not fewer than 333 millions of inhabitants. As the extent of the country is 1,297,999 ſquare miles, there are of courſe very near 260 inhabitants to every ſquare mile; and of theſe miles a very conſiderable proportion conſiſts of nothing but barren rocks. That this account is accurate there can be little doubt; for the extent of the provinces was aſcertained by aſtronomical obſervations, as well as by admeaſurement; and the number of individuals is regularly taken in each diviſion of a diſtrict by a tythingman, or every tenth maſter of a family. Theſe returns are collected by officers reſident ſo near as to be capable of correcting any groſs miſtake, and are all lodged in the great regiſter of Pekin.

For this exceſſive population our author ſatisfactorily accounts. Celibacy, ſays he, is rare in China, even in the military profeſſion; the marriages are prolific as well as early, and the influence of the patriarchal ſyſtem, to be explained afterwards, is ſuch, that a man's children adds to his wealth. It is reckoned a diſcredit to be without offſpring; and they who have none adopt others, who become theirs excluſively. In caſe of marriage, ſhould a wife prove barren, a ſecond may be eſpouſed in the lifetime of the firſt. The opulent, as in moſt parts of the Eaſt, are allowed, without reproach, to keep concubines, of whom the children are conſidered as being thoſe of the legitimate wife, and partake in all the rights of legitimacy. "Accidents ſometimes of extraordinary drought, and ſometimes of exceſſive inundations, occaſionally produce famine in particular provinces, and famine diſeaſe; but there are few drains from moral cauſes either of emigration or foreign navigation. The number of manufacturers, whoſe occupations are not always favourable to health, whoſe conſtant confinement to particular ſpots, and ſometimes in a cloſe or tainted atmoſphere, muſt be injurious, and whoſe reſidence in towns expoſes them to irregularities, bears but a very ſmall proportion to that of huſbandmen in China. In general there ſeems to be no other bounds to Chineſe populouſneſs than thoſe which the neceſſity of ſubſiſtence may put to it. Theſe boundaries are certainly more enlarged than in other countries. The whole ſurface of the empire is, with trifling exceptions, dedicated to the production of food for man alone. There is no meadow, and very little paſture; nor are fields cultivated in oats, beans, or turnips, for the ſupport of cattle of any kind. Few parks or pleaſure grounds are ſeen, excepting thoſe belonging to the emperor. Little land is taken up for roads, which are few and narrow, the chief communication being by water. There are no commons, or lands ſuffered to lie waſte by the neglect, or the caprice, or for the ſport of great proprietors. No arable land lies fallow. The ſoil, under a hot and fertilizing ſun, yields annually, in moſt inſtances, double crops, in conſequence of adapting the culture to the ſoil, and of ſupplying its defects by mixture with other earths, by manure, by irrigation, by careful and judicious induſtry of every kind. The labour of man is little diverted from that induſtry to miniſter to the luxuries of the opulent and powerful, or in employments of no real uſe. Even the ſoldiers of the Chineſe army, except during the ſhort intervals of the guards, which they are called to mount, or the exerciſes, or other occaſional ſervices which they perform, are moſtly employed in agriculture. The quantity of ſubſiſtence is increaſed alſo by converting more ſpecies of animals and vegetables to that purpoſe than is uſual in other countries. And even in the preparation of their food, the Chineſe have economy and management."

The government of China is deſpotic; and it is a curious ſpectacle to behold ſo large a proportion of the whole human race, connected together in one great ſyſtem of polity, ſubmitting quietly, and through ſo conſiderable an extent of country, to one great ſovereign; and uniform in their laws, their manners and their language, but differing eſſentially in each of theſe reſpects from every other portion of mankind; and neither deſirous of communicating with nor forming any deſigns againſt the reſt of the world. To produce ſuch a phenomenon, many cauſes muſt be combined; but perhaps the principal are to be found in the patriarchal ſyſtem already mentioned, in the laws and cuſtoms of the empire, and in the belief that the emperor is the vicegerent of heaven, and guided in all his actions by divine inſpiration.

The patriarchal ſyſtem is founded upon that filial piety which the philoſophers of China have uniformly repreſented as the greateſt of human virtues. Theſe ſages, while they ſucceſsfully inculcated this duty, have left parental affection to its own natural influence; and hence in China parents are leſs frequently neglected than infants are expoſed. The laws of the empire, to corroborate the diſpoſition to filial obedience, furniſh an opportunity for puniſhing any breach of it, by leaving a man's offſpring entirely within his own power: and hence it is, that with the poor, marriage, as we have ſaid, is a meaſure of prudence; becauſe the children, particularly the ſons, are bound to maintain their parents.

A Chineſe dwelling is generally ſurrounded by a wall ſix or ſeven feet high. Within this incloſure a whole family, of three generations, with all their reſpective wives and children, will frequently be found. One ſmall room is made to ſerve for the individuals of each well as poliſhed manners. They are, however, in general, fitter for military than civil offices. The hardy education, the rough manners, the active ſpirit, the wandering diſpoſition, the looſe principles, and the irregular conduct, of the Tartar, fit him better for the profeſſion, practice, and purſuits of war, than the calm, regulated, and domeſtic habits of the Chineſe. Warriors ſeem naturally the offspring of Tartary, as literati are of China; and accordingly, the principal military commands are conferred on natives of the former country, as, with many exceptions indeed, the chief civil offices are on thoſe of the latter.

A military mandarin, who was much with Lord Macartney, and was himſelf a diſtinguiſhed officer, aſſerted, that, "including Tartars, the total of the army in the pay of China, amounted to 1,000,000 infantry, and 800,000 cavalry. From the obſervations made by the embaſſy in the courſe of their travels through the empire, of the garriſons in the cities of the ſeveral orders, and of the military poſts at ſmall diſtances from each other, there appeared nothing unlikely in the calculation of the infantry; but they met few cavalry. If the number mentioned really do exiſt, a great proportion of them muſt have been in Tartary, or on ſome ſervice diſtant from the route of the embaſſy.

"Of the troops, eſpecially cavalry, a vaſt number are Tartars, who have a higher pay than their Chineſe fellow-ſoldiers. The principal officers of confidence in the army are Tartars alſo. None of either nation are received into the ſervice, but ſuch as are healthy, ſtrong, and ſightly. The pay and allowances of a Chineſe horſeman are three Chineſe ounces, heavier than European ounces, and three-tenths of an ounce, of ſilver, and fifteen meaſures or rations (the weight not mentioned) of rice every lunar month. A Tartar horſeman, ſeven ſimilar ounces of ſilver, and 20 meaſures of rice for the ſame period. A Chineſe foot ſoldier has one ounce and ſix tenths of an ounce of ſilver, and ten meaſures of rice; and a Tartar of the ſame deſcription has two ounces of ſilver, and ten meaſures of rice every lunar month. The emperor furniſhes the arms, accoutrements, and the upper garment, to all the ſoldiers. Beſide their ordinary pay and allowances, they alſo receive donations from the emperor on particular occaſions; as when they marry, and when they have male children born. On the death of their parents they obtain 'a gift of conſolation;' as do their families when the ſoldiers themſelves die.

"The public revenues of China Proper are ſaid to be little leſs than 200,000,000 of ounces of ſilver, which may be equal to about 66,000,000 of pounds ſterling; or about three times thoſe of France before the late ſubverſion. From the produce of the taxes all the civil and military expences, and the incidental and extraordinary charges are firſt paid upon the ſpot out of the treaſuries of the reſpective provinces, where ſuch expences are incurred; and the remainder is remitted to the Imperial treaſury at Pekin. This ſurplus amounted, in the year 1792, to the ſum of 36,614,328 ounces of ſilver, or 12,204,776 pounds ſterling, according to an account taken in round numbers. In caſe of inſurrections, or other occurrences requiring extraordinary expences, they are generally levied by additional taxes on the provinces adjacent to the ſcene of action, or connected with the occaſion of the expence.

"In the adminiſtration of the vaſt revenue of the ſtate, the opportunities of committing abuſes are not often neglected; as may be inferred from the frequent confiſcation to the emperor, in conſequence of ſuch tranſgreſſions. It is indeed affirmed, that much corruption and oppreſſion prevail in moſt of the public departments, by which conſiderable fortunes are acquired, notwithſtanding the modicity of the public ſalaries."

With ſuch a ſtanding army, and ſo vaſt a revenue, it will no longer appear wonderful that one man ſhould govern with deſpotic ſway, even the immenſe multitude of people who inhabit the empire of China, eſpecially trained up as thoſe people are in habits of filial ſubmiſſion to their ſuperiors. But there are ſome circumſtances in the ſyſtem of Chineſe policy, not yet mentioned, which contribute perhaps more than even theſe habits and that power to preſerve the ſtability of the government. The emperor reſerves to himſelf alone the right of relieving the wants of the poor, produced by famine or any other unforeſeen calamity. On ſuch occaſions he always comes forward. He orders the public granaries to be opened; remits the taxes to thoſe who are viſited with misfortune; affords aſſiſtance to enable them to retrieve their affairs; and appears to his ſubjects as ſtanding almoſt in the place of Providence in their favour. He is perfectly aware by how much a ſtronger chain he thus maintains his abſolute dominion, than the mere dread of puniſhment would afford. The emperor, to whom the Britiſh embaſſy was ſent, ſhewed himſelf ſo jealous of retaining the excluſive privilege of benevolence to his ſubjects, that he not only rejected, but was offended at, a propoſal once made to him by ſome conſiderable merchants, to contribute towards the relief of a ſuffering province; whilſt he ſcrupled not, at the ſame time, to accept the donation of a rich widow towards the expences of a war in which he was engaged.

This veneration, excited towards the emperor by his apparent benevolence, is increaſed by an opinion zealouſly inſtilled into the people, that he has the faculty of predicting future events of the greateſt importance. The Chineſe, given up to the dotages of judicial aſtrology, are firmly perſuaded that eclipſes of the ſun and moon have a powerful influence on the operations of nature and the tranſactions of mankind; and the periods of their occurrence become, of courſe, objects of attention and ſolicitude. The government of the country, ever anxious to eſtabliſh its authority in the general opinion of its ſuperior wiſdom and conſtant care for the welfare of the people, employs the European miſſionaries at Pekin (for it is doubtful if any one of the natives has ſo much ſcience) to calculate eclipſes, and then announces them to the people with that ſolemnity which is fitted to enſure veneration for the ſuperintending power whence ſuch knowledge is immediately derived to them. Eclipſes of the ſun, in particular, are conſidered as ominous of ſome general calamity; and as great pains are taken to inſpire them with a belief that their proſperity is owing to the wiſdom and virtues of their ſovereign, ſo they are tempted to attribute to ſome deficiency on his part whatever they think portentous. To this prejudice the emperor finds it prudent to accommodate his conduct. He never ventures on any undertaking of importance at the approach of a ſolar eclipſe, but affects to withdraw himſelf from the preſence of his courtiers, to examine ſtrictly into his late adminiſtration of the empire, in order to correct any error, for the commiſſion of which the eclipſe may have been an admonition. On theſe occaſions he invites his ſubjects to give him freely their advice: but it is plain that advice muſt be offered with great deference to a being for whoſe admonition the motions of the ſun and moon are believed to be regulated; and while ſuch notions are implicitly admitted, the perſon of the Chineſe emperor, as well as his authority, muſt be looked upon by his ſubjects as ſomething more than human.

This is in fact the caſe. He is not only approached in perſon with teſtimonies of the utmoſt reſpect, but is adored when abſent with all the rites and ceremonies which are uſed by the Chineſe in the worſhip of their divinities. On his birth-day, at the new and full moon, and probably on other feſtivals, all the mandarines reſident in the neighbourhood of any of his numerous palaces aſſemble about noon, and repairing to the palace, ſolemnly proſtrate themſelves nine times before the throne, their foreheads ſtriking the floor each time; whilſt incenſe is burning on tripods on each ſide of it, and offerings are made, on an altar before it, of tea and fruits to the ſpirit of the abſent emperor. Over the throne are ſeen the Chineſe characters of glory and perfection; and the name of the Deity is given to the emperor, who is conſidered by his votaries as poſſeſſing in ſome ſenſe the attribute of ubiquity. Mr Barrow, one of the gentlemen of the embaſſy, was preſent at *Yuen-min-yuen*, one of the imperial palaces, when theſe idolatrous rites of adoration were performed, and he was aſſured that they took place on that day in all parts of the empire, the proſtraters being every where attentive to turn their faces towards the capital.

That he who claims adoration in his abſence does not appear on his birth-day to receive the compliments of his ſubjects, will not ſurpriſe the reader. The manner in which that feſtival is celebrated at the palace, where the emperor happens to be reſident, is thus deſcribed by Sir George Staunton, who witneſſed this more than auguſt ceremony at the palace of *Zhe-hal* in Tartary. "The princes, tributaries, ambaſſadors, great officers of ſtate, and principal mandarines, were aſſembled in a vaſt hall; and upon particular notice, were introduced into an inner building, bearing, at leaſt, the ſemblance of a temple. It was chiefly furniſhed with great inſtruments of muſic, among which were ſets of cylindrical bells, ſuſpended in a line from ornamented frames of wood, and gradually diminiſhing in ſize from one extremity to the other, and alſo triangular pieces of metal arranged in the ſame order as the bells. To the ſound of theſe inſtruments a ſlow and ſolemn hymn was ſung by eunuchs, who had ſuch a command of their voices as to reſemble the effect of the muſical glaſſes at a diſtance. The performers were directed, in gliding from one tone to another, by the ſtriking of a ſhrill and ſonorous cymbal; and the judges of muſic among the gentlemen of the embaſſy were much pleaſed with their execution. The whole had indeed a grand effect. During the performance, and at particular ſignals, nine times repeated, all the perſons proſtrated themſelves nine times, except the ambaſſador and his ſuite, who made a profound obeiſance (A). But he whom it was meant to honour, continued, as if it were in imitation of the Deity, inviſible the whole time."

That the awful impreſſion meant to be made upon the minds of men by this apparent worſhip of a fellow-mortal might not be too quickly effaced, all ſcenes of ſport and gaiety were poſtponed to the next day, when a variety of entertainments was exhibited in the preſence of the emperor, ſurrounded by his court and tributary princes.

Notwithſtanding the general veneration of the Chineſe for the perſon and government of their emperor, the mandarines aſſerted that a ſect had for ages ſubſiſted in the country, whoſe chief principles were founded on an antipathy to monarchy, and who nouriſhed hopes of at laſt ſubverting it. Their meetings were held in the utmoſt ſecrecy, and no man avowed any knowledge of them; but a ſort of inquiſition was ſaid to be eſtabliſhed in order to find them out, and they who were ſuſpected of ſuch ſentiments were cut off, or hunted out of ſociety. Should the French declaration of the rights of man, which, through the zeal of its authors, has been tranſlated into one of the languages of India, find its way into China (of which the court is ſaid to be much afraid), it would indeed be a powerful engine in the hands of this ſecret ſect to ſap the foundations of the ancient government. The minds of many of the Chineſe are far from ſatisfied with their condition, which lays both their perſons and their fortunes at the mercy of the mandarines. No private man in China is exempted from corporal puniſhment, which may be inſtantly inflicted on him at the nod of a magiſtrate; and when he has occaſion to ſpeak to a great mandarine, he is obliged, by the police of the country, to throw himſelf on his knees, and in that poſture to communicate his buſineſs. The mandarine himſelf, on the other hand, lies under the hardſhip of being frequently reſponſible for events which he could not controul. Upon the general principal that it is his duty to watch over the morals of the people, he is in many caſes conſidered as a criminal for not preventing crimes which he had not been able to prevent. The mandarines are thus aware of not being guaranteed by good conduct againſt diſgrace; and feeling the chagrin of inſecurity, many of them

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(A) The Chineſe court, which conſiders all other ſovereigns as ſubordinate to their own, exacts from foreign miniſters, as well as from natives of the empire, nine proſtrations upon their firſt introduction to the emperor. This demand was made, in the laſt century, of the Dutch, who inſtantly complied with it in hopes of obtaining in return ſome lucrative advantages; and the conſequence was, that their ambaſſador was treated with neglect, and diſmiſſed without promiſe of the ſmalleſt favour. It was likewiſe made of a Ruſſian ambaſſador in the preſent century; but he would not comply with it, until a regular agreement was made for its return, on a like occaſion, to his own ſovereign. Lord Macartney, who was repeatedly urged to go through the ſame abject ceremony, diſplayed ſuch firmneſs and addreſs, that after much evaſion it was at laſt announced to him, that his imperial majeſty would be ſatisfied with the ſame form of reſpectful obedience that the Engliſh are in the habit of paying to their own ſovereign; and upon theſe terms his lordſhip was introduced and graciouſly received.

them muſt doubtleſs be ripe for a revolt. Fear may keep them quiet during the reign of a ſovereign poſſeſſed of abilities and vigilance; but the maxims which regulate the imperial ſucceſſion are ſuch, that a firm confederacy could hardly fail at the death of an emperor to introduce great changes into the conſtitution. The throne of China is neither hereditary nor elective. The choice of a ſucceſſor is left entirely to the reigning prince, who may exclude, as has been inſtanced, even his own offspring and family. To prevent commotions and fraud, it is no uncommon practice for the emperor, during his lifetime, to declare his ſucceſſor; for when his ſucceſſion is ſettled by a written teſtament, the throne is not always filled by him for whom it was deſtined. The father of the emperor to whom the Britiſh embaſſy was ſent, is ſaid to have obtained poſſeſſion of the throne by ſuddenly entering the palace in the laſt moments of his predeceſſor, and ſubſtituting his own name in a teſtament intended for the exaltation of another.

To what has been ſaid in the Encyclopædia of the religion of the Chineſe, we have here very little to add. Various deities are worſhipped in the empire by very different rites and ceremonies; but there is in China no ſtate religion. None is paid, preferred, or encouraged by it. The emperor is of one faith; many of the mandarines of another; and the majority of the common people of a third, which is that of Fo. The men of letters venerate rather than adore Confucius; and meet to honour and celebrate his memory in halls of a ſimple but neat conſtruction. The numerous and lower claſſes of the people are leſs able than inclined to contribute much towards the erection of large and coſtly edifices for public worſhip: their attention is almoſt wholly engaged by their houſehold gods; for every houſe has its altar and its deities.

“No people are, in fact, more ſuperſtitious than the common Chineſe. Beſide the habitual offices of devotion on the part of the prieſts and females, the temples are particularly frequented by the diſciples of Fo previouſly to any undertaking of importance; whether to marry, or go a journey, or conclude a bargain, or change ſituation, or for any other material event in life, it is neceſſary firſt to conſult the ſuperintendant deity. This is performed by various methods. Some place a parcel of conſecrated ſticks, differently marked and numbered, which the conſultant, kneeling before the altar, ſhakes in a hollow bamboo, until one of them falls on the ground; its mark is examined, and referred to a correſpondent mark in a book which the prieſt holds open, and ſometimes even it is written upon a ſheet of paper paſted upon the inſide of the temple. Polygonal pieces of wood are by others thrown into the air. Each ſide has its particular mark; the ſide that is uppermoſt when fallen on the floor is in like manner referred to its correſpondent mark in the book or ſheet of fate. If the firſt throw be favourable, the perſon who made it proſtrates himſelf in gratitude, and undertakes afterwards with confidence the buſineſs in agitation. But if the throw ſhould be adverſe, he tries a ſecond time, and the third throw determines, at any rate, the queſtion. In other reſpects, the people of the preſent day ſeem to pay little attention to their prieſts. The temples are, however, always open for ſuch as chooſe to conſult the decrees of heaven. They return thanks when the oracle proves propitious to their wiſhes. Yet they oftener caſt lots to know the iſſue of a projected enterpriſe than ſupplicate for its being favourable; and their worſhip conſiſts more in thankſgiving than in prayer.

“The Chineſe are ſaid ſeldom to carry the objects to be obtained by their devotion beyond the benefits of this life. Yet the religion of Fo profeſſes the doctrine of the tranſmigration of ſouls, and promiſes happineſs to the people on conditions, which were no doubt originally intended to conſiſt in the performance of moral duties: but in lieu of which are too frequently ſubſtituted thoſe of contributions towards the erection or repair of temples, the maintenance of prieſts, and a ſtrict attention to particular obſervances. The neglect of theſe is announced as puniſhable by the ſouls of the defaulters paſſing into the bodies of the meaneſt animals, in whom the ſufferings are to be proportioned to the tranſgreſſions committed in the human form.”

Though the Chineſe artiſts are very ingenious as mere workmen, there is hardly any thing which deſerves the name of ſcience in the whole empire. So little is the ſtudy of mathematics cultivated, that there are few ſhopkeepers in China who can perform the ordinary operations of arithmetic; but caſt up their accounts by means of an inſtrument called *Swanpan* (See Swanpan, *Encycl.*). Though the compoſition of gunpowder was certainly known in China much earlier than in Europe, and though the Chineſe had employed it from the beginning in blaſting rocks, and in making a vaſt variety of fire-works; yet Sir George Staunton ſeems convinced, that they never thought of the invention of guns till they were taught by the Europeans to introduce them into their armies.

The ſtate of phyſic in this vaſt country is extremely low, being nowhere taught in public ſchools or colleges. “A young man, who wiſhes to become a phyſician, has no other way of acquiring medical knowledge than by engaging himſelf to ſome practitioner as an apprentice. He has thus the opportunity of ſeeing his maſter's practice, of viſiting his patients with him, and of learning ſuch parts of his knowledge and ſecrets as the other chooſes to communicate to him. The emoluments of the profeſſion ſeldom exceed the ſkill of the practitioner. As many copper coin as ſcarcely are equal to ſixpence ſterling is ſaid to be the uſual fee among the people; and perhaps quadruple among the mandarines. Medicine is not divided in China into diſtinct branches as in moſt parts of Europe. The ſame perſon acts as phyſician, ſurgeon and apothecary. The ſurgical part of the profeſſion is ſtill more backward than the others. Amputation, in caſes of compound fracture and gangrene, is utterly unknown; and death is the ſpeedy conſequence of ſuch accidents. The Chineſe method of inoculation, which was introduced into the empire about the beginning of the tenth century of our era, is as follows: When the diſeaſe breaks out in any diſtrict, the phyſicians of the place carefully collect a quantity of ripe matter from puſtules of the proper ſort; which being dried and pulveriſed is cloſely ſhut up in a porcelain jar, ſo as to exclude from it the atmoſpheric air; and in this manner it will retain its properties for many years. When the patient has been duly prepared by medicines, generally of an aperient kind, and ſtrictly dieted for a ſhort time, a lucky day is choſen to ſprinkle preciſion, and with the help of the beſt inſtruments, bear the following proportion to our weights : The kin is equal to one pound 12 ounces 2 drachms 24 grains ; the leang one ounce one drachm 60 grains ; the tſien 70 grains $\frac{8}{10}$; the fen 7 grains $\frac{8}{100}$. Conſequently the laſt of this ſeries, the ſun, amounts to no more than 0 grains 000000000708.

CHINESE *Wheel* is an engine employed in the province of *Kiang-ſee*, and probably through the whole empire, for raiſing water from rivers to irrigate plantations of ſugar canes, on a ſandy ſoil, conſiderably elevated above the level of the river. By Sir George Staunton, who ſays that it is ingenious in its contrivance, cheap in its materials, eaſy in its operation, and effectual to its purpoſe, it is thus deſcribed :

" Two hard wood poſts or uprights are firmly fixed in the bed of the river, in a line perpendicular to its bank. Theſe poſts ſupport the axis about ten feet in length, of a large and durable wheel, conſiſting of two unequal rims, the diameter of one of which, cloſeſt to the bank, being about fifteen inches ſhorter than that of the outer rim ; but both dipping in the ſtream, while the oppoſite ſegment of the wheel riſes above the elevated bank. This double wheel is connected with the axis, and is ſupported by 16 or 18 ſpokes obliquely inſerted near each extremity of the axis, and croſſing each other at about two-thirds of their length. They are there ſtrengthened by a concentric circle, and faſtened afterwards to the rims : the ſpokes inſerted in the interior extremity of the axis reaching the outer rim, and thoſe proceeding from the exterior extremity of the ſame axis, reaching the inner and ſmaller rim. Between the rims and the croſſing of the ſpokes is woven a kind of cloſe baſket-work, ſerving as ladle-boards or floats, which meeting ſucceſſively the current of the ſtream, obey its impulſe, and turn round the wheel. To both its rims are attached ſmall tubes or ſpouts of wood, with an inclination of about 25 degrees to the horizon, or to the axis of the wheel. The tubes are cloſed at their outer extremity, and open at the oppoſite end. By this poſition, the tubes which happen in the motion of the wheel to be in the ſtream with their mouths or open ends uppermoſt, fill with water. As that ſegment of the wheel riſes, the mouths of the tubes attach to it, alter their relative inclination, but not ſo much as to let their contents flow out till ſuch ſegment of the wheel becomes the top. The mouths of thoſe tubes are then relatively depreſſed, and pour the water into a wide trough placed on poſts, from whence it is conveyed as may be wanted among the canes.

" The only materials employed in the conſtruction of this water-wheel, except the nave or axis, and the poſts on which it reſts, are afforded by the bamboo. The rims, the ſpokes, the ladle-boards or floats, and the tubes or ſpouts, and even the cords, are made of entire lengths, or ſingle joints, or large pieces, or thin ſlices of the bamboo. Neither nails, nor pins, nor ſcrews, nor any kind of metal enters into its conſtruction. The parts are bound together firmly by cordage, alſo of ſlit bamboo. Thus at a very trifling expence, is conſtructed a machine, which, without labour or attendance will furniſh, from a conſiderable depth, a reſervoir with a conſtant ſupply of water adequate to every agricultural purpoſe.

" Theſe wheels are from 20 to 40 feet in diameter, according to the height of the bank and conſequent elevation to which the water is to be raiſed. Such a wheel is capable of ſuſtaining with eaſe 20 tubes or ſpouts, of the length of four feet, and diameter two inches in the clear. The contents of ſuch a tube would be equal to ſix-tenths of a gallon, and a periphery of 20 tubes, twelve gallons. A ſtream of a moderate velocity would be ſufficient to turn the wheel at the rate of four revolutions in one minute, by which would be lifted 48 gallons of water in that ſhort period ; in one hour, 2880 gallons ; and 69120 gallons, or upwards of 300 tons of water, in a day."

Sir George, who ſaw this wheel in motion, thinks it preferable in many reſpects to any machine yet in uſe for ſimilar purpoſes. He obſerves, that, while it approaches near to the Perſian wheel, of which a deſcription and figure is given in the article HYDROSTATICS *(Encycl.)*, it is more ſimple than that wheel in its contrivance, and much leſs expenſive. This is indeed true ; but the ſimpleſt engine of the kind, and therefore the beſt that has yet been invented, is perhaps that which is employed to throw water into the moſs of Blair Drummond in Perthſhire. See Moss *(Encycl.)*

CHIPPAWAY, an inconſiderable place near the falls of Niagara, 10 miles from Queenſtown.—*Morse.*

CHIPPEWAY *River* runs S. weſtward into Miſſiſſippi River in that part where the confluent waters form lake Pepin, in N. lat. 44. W. long. 93. 54.—*ib.*

CHISSEL, a fort in the ſtate of Tenneſſee, 24 miles from Engliſh ferry, on New river ; 43 from Abingdon, and 107 from Long iſland, on Holſton.—*ib.*

CHITTENDEN *Co.* in Vermont, lies on lake Champlain, between Franklin co. on the N. and Addiſon S. ; La Moille river paſſes through its N. W. corner, and Onion river divides it nearly in the center. Its chief town is Burlington. This county contained, by the cenſus of 1791, 44 townſhips and 7301 inhabitants. Since that time the northern counties have been taken from it, ſo that neither its ſize or number of inhabitants can now be aſcertained.—*ib.*

CHITTENDEN, a townſhip in Rutland co. Vermont, contains 159 inhabitants. The road over the mountain paſſes through this townſhip. It lies 7 miles E. from the fort on Otter creek, in Pittsford, and about 60 N. by E. from Bennington.—*ib.*

CHITTENENGO, or *Canaſerage*, a conſiderable ſtream which runs northerly into lake Oneida in the ſtate of New-York.—*ib.*

CHOCOLATE *Creek*, a head-water of Tioga River in New-York, whoſe mouth lies 10 miles S. W. of the Painted Poſt.—*ib.*

CHOCOPE, a town in the juriſdiction of Truxillo, in S. America, in Peru ; 14 leagues ſouthward of St Pedro. Here are about 90 or 100 houſes, and about 60 or 70 families, chiefly Spaniards, with ſome of the other caſts, but not above 25 Indian families. It has a church built of brick, both large and decent. The people here mention a rain that fell in 1726, which laſted 40 nights, beginning conſtantly at 4 or 5 in the evening, and ceaſing at the ſame hour next morning, which laid moſt of the houſes in ruins. S. lat. 7. 46.—*ib.*

CHOCORUA, a mountain in Grafton co. New-Hampſhire, on the N. line of Stafford co. N. of Tamworth.—*ib.*

CHOCUITO, or rather *Chucuito*, or *Titi Caca*, a large lake near Paria, in S. America, and in Peru, into which a great number of rivers empty themſelves. It is 240 miles in circumference, and in ſome parts 80 fathoms deep; yet the water cannot be drunk, it is ſo very turbid. It abounds in fiſh, which they dry and ſalt, and exchange with the neighboring provinces for brandy, wines, meal, or money. It is ſaid the ancient Yncas, on the conqueſt of Peru, by the Spaniards, threw into this lake, all their riches of gold and ſilver. It was this lake into which the Ynca Huana Capac, threw the famous chain of gold, the value of which was immenſe. It abounds with flags and ruſhes, of which Capac Vupanchi, the fifth Ynca, built a bridge, for tranſporting his army to the other ſide.—*ib.*

CHOISEUL *Bay*, on the N. W. coaſt of the iſlands of the Arſacides, W. of Port Praſlin. The inhabitants on this bay, like thoſe at Port Praſlin, have a cuſtom of powdering their hair with lime, which burns it and gives it a red appearance.—*ib.*

CHOPINE, CHOPPINE, or CHOPEENE, a high ſhoe, or rather clog, worn 200 years ago, by the Italians.

Tom Coryat, in his Crudities 1611, p. 262, calls them *chapineys*, and gives the following account of them: "There is one thing uſed of the Venetian women and ſome others dwelling in the cities and towns ſubject to the ſigniory of Venice, that is not to be obſerved, I thinke, amongſt any other women in Chriſtendome, which is ſo common in Venice, that no women whatſoever goeth without it, either in her houſe or abroad, *a thing made of wood and covered with leather of ſundry colors, ſome with white, ſome redde, ſome yellow. It is called a* chapiney, *which they wear under their ſhoes.* Many of them are curiouſly painted; ſome alſo of them I have ſeen fairly gilt; ſo uncomely a thing, in my opinion, that it is pitty this fooliſh cuſtom is not cleane baniſhed and exterminated out of the citie. *There are many of theſe chapineys of a great height, even half a yard high,* which maketh many of their women that are very ſhort ſeem much taller than the talleſt women we have in England. Alſo I have heard it obſerved among them, that by how much the nobler a women is, by ſo much the higher are her *chapineys.* All their gentlewomen, and moſt of their wives and widows that are of any wealth, are aſſiſted eyther by men or women when they walke abroad, to the end they may not fall. They are borne up moſt commonly by the left arme, otherwiſe they might quickly take a fall."

CHOPTANK, a large navigable river on the eaſtern ſhore of Maryland, emptying into Cheſapeak bay. —*Morse.*

CHOWAN *Co.* in Edenton diſtrict, N. Carolina, on the N. ſide of Albemarle ſound. It contains 5011 inhabitants, of whom 2588 are ſlaves. Chief town, Edenton.—*ib.*

CHOWAN *River*, in N. Carolina, falls into the N. W. corner of Albemarle ſound. It is 3 miles wide at the mouth, but narrows faſt as you aſcend it. It is formed 5 miles from the Virginia line, by the confluence of Meherrin, Nottaway, and Black rivers, which all riſe in Virginia.—*ib.*

CHOWDRY, in Bengal, the poſſeſſor of ſeveral *Talooks*. It is alſo uſed as ſynonymous with *Talookdar*, anciently a collector. See TALOOK in this Supplement.

CHRISOM was not, as is ſaid in the Encyclopædia, a face-cloth or piece of linen laid over the child's head when it was baptized; but it was a white veſture or garment, which, immediately after it was baptized, the prieſt put upon it, ſaying, "Take this white veſture as a token of the innocency which, by God's grace in this holy ſacrament of baptiſm, is given unto thee, and for a ſign whereby thou art admoniſhed, ſo long as thou liveſt, to give thyſelf to innocence of living, that after this tranſitory life thou mayeſt be partaker of life everlaſting. Amen."

As ſoon as the prieſt had pronounced theſe words, he anointed the infant upon the head, ſaying, "Almighty God, the Father of our Lord Jeſus Chriſt, who hath regenerated thee by water and the Holy Ghoſt, and hath given unto thee the remiſſion of all thy ſins; he vouchſafe to anoint thee with the unction of his Holy Spirit, and bring thee to the inheritance of everlaſting life. Amen."

It was from this anointing or *chriſm* that the white garment got the name of *chriſom*, which, after being worn a few days, was offered to the prieſt to be kept in the church or veſtry, in order to be produced as evidence againſt the perſon whoſe chriſom it was, ſhould he afterwards deny the faith in which he had been baptized. Theſe ceremonies were retained, for ſome time after the reformation, in the church of England, which ordered the mother of the child (if the child was then alive, to offer, when ſhe was churched, the *chriſom* and other accuſtomed offerings. If the child died before its mother was churched, the *chriſom* was not given to the prieſt, but employed as a ſhroud, in which the body was buried; and hence it is that chriſoms are now enumerated, moſt abſurdly indeed, in the weekly bills of mortality. We ſay abſurdly; becauſe children who die unbaptized are called *chriſoms*, though the chriſom, when it was uſed, was never put on till baptiſm. See *Whitby on the Book of Common Prayer, &c.*

CHRIST CHURCH, a pariſh in Charleſton diſtrict, S. Carolina, containing 2954 inhabitants, of whom 566 are whites, 2377 ſlaves.—*Morſe.*

CHRISTIANA, a poſt town in New-Caſtle co Delaware, is ſituated on a navigable creek of its name, 12 miles from Elkton, 9 S. W. of Wilmington, and 37 S. W. of Philadelphia. The town, conſiſting of about 50 houſes, and a preſbyterian church, ſtands on a declivity which commands a pleaſant proſpect of the country towards the Delaware. It carries on a briſk trade with Philadelphia in flour. It is the greateſt carrying place between the navigable waters of the Delaware and Cheſapeak; which are 13 miles aſunder at this place. It was built by the Swedes, in 1640, and thus called after their queen.—*ib.*

CHRISTIANA *Creek*, on which the above town is ſituated, falls into Delaware river from the S. W. a little below Wilmington.

It is propoſed to cut a canal of about 9 miles in length, in a S. weſtern direction from this creek, at the town of Chriſtiana (6 miles W. S. W. of New-Caſtle) to Elk river in Maryland, about a mile below Elkton. —*ib.*

CHRISTIANA, ST, one of the Marqueſa iſles, called by the natives Waitahû, lies under the ſame parallel with St Pedro, 3 or 4 leagues more to the weſt. Reſolution bay, near the middle of the W. ſide of the iſland, is in lat. 9. 55. 30. S. long. 139. 8. 40. W. from Greenwich; and the W. end of Dominica N. 15.

W. Capt. Cook gave this bay the name of his ſhip. It was called Port Madre de Dios by the Spaniards. This iſland produces cotton of a ſuperior kind. A ſpecimen of it is depoſited in the muſeum of the Maſſ. Hiſt. Society.—*ib.*

CHRISTIANSBURG, the chief town of Montgomery co. Virginia. It contains very few houſes; has a court-houſe and gaol, ſituated near a branch of Little river, a water of the Kanhaway. N. lat. 37. 5.—*ib.*

CHRISTIANSTED, the principal town in the iſland of Santa Cruz, ſituated on the N. ſide of the iſland, on a fine harbor. It is the reſidence of the Daniſh governor, and is defended by a ſtone fortreſs.—*ib.*

CHRISTMAS *Iſland*, in the Pacific ocean, lies entirely ſolitary, nearly equally diſtant from the Sandwich iſlands on the N. and the Marqueſas on the S. It was ſo named by captain Cook, on account of his firſt landing there, on Chriſtmas day. Not a drop of freſh water was found by digging. A ſhip touching at this deſolate iſle muſt expect nothing but turtle, fiſh, and a few birds. It is about 15 or 20 leagues in circumference, and bounded by a reef of coral rocks, on the W. ſide of which there is a bank of fine ſand, extending a mile into the ſea, and affording good anchorage. N. lat. 1. 59. W. long. 157. 30.—*ib.*

CHRISTMAS *Sound*, in Terra del Fuego, South America, in N. lat. 55. 21. W. long. 69. 57.—*ib.*

CHRONOLOGICAL CHARACTERS are characters by which times are diſtinguiſhed. Of theſe ſome are natural or aſtronomical; others, artificial or hiſtorical. The natural characters are ſuch as depend on the motions of the ſtars or luminaries, as *eclipſes*, *ſolſtices*, *equinoxes*, the *different aſpects of the planets*, &c. The artificial characters are thoſe that have been invented and eſtabliſhed by men; as the *ſolar cycle*, the *lunar cycle*, &c. Hiſtorical chronological characters are thoſe ſupported by the teſtimony of hiſtorians, when they fix the *dates* of certain *events* to certain *periods*. *Hutton's Mathematical Dictionary*.

CHRONOSCOPE, a word ſometimes uſed to denote a pendulum or machine to meaſure time.

CHUCKIAH, in Bengal, the juriſdiction of a *Fogedar*. See FOGEDAR in this Supplement.

CHURCH is a word which has many different ſignifications, all ſufficiently explained in the Encyclopædia, where there is likewiſe given a conciſe *hiſtory* of the Chriſtian church (ſee HISTORY, Sect. ii.), defective, indeed, but perhaps not more ſo than was to be expected from the limits of the work and the extent of the ſubject.

Of the conſtitution of the primitive and apoſtolical church, no man can have a correct notion who has not taken the trouble to conſult the primitive and apoſtolical writers; for, as we have elſewhere obſerved, all modern compilers of eccleſiaſtical hiſtory are more or leſs prejudiced in behalf of the particular church to which they belong, and wreſt the language of the original writers ſo as to make them bear witneſs to the antiquity of *modes of faith* and *eccleſiaſtical polity*, which are not perhaps a hundred years old.

On this account we ſhall not here attempt to correct what we really think the miſtakes of him who compiled the ſection of eccleſiaſtical hiſtory in the Encyclopædia. Moſheim and Sir Peter King, whom he ſeems to have implicitly followed, were indeed great men; and it would be folly to deny that the *Hiſtory* of the former, and the *Inquiry* of the latter, *into the Conſtitution of the Primitive Church*, are works of learning and ingenuity; but it is not perhaps too much to ſay, that both authors wrote under the influence of prejudice. Our readers will diſcover how cloſely either the one or the other has adhered to truth, by ſtudying the eccleſiaſtical writers of the firſt four centuries. Such a ſtudy will make them acquainted with the doctrines, diſcipline, and worſhip of the church before it was incorporated with the ſtate; and we know not that kind of knowledge which is of more importance to the divine, however much it may be deſpiſed in this age of affected ſcience and real ignorance.

Of the principal churches at preſent exiſting, a pretty full account is given in the Encyclopædia, either under their different denominations, or under the titles of thoſe tenets by which they are chiefly diſtinguiſhed; ſo that from that Work alone a reader may form a tolerably accurate notion of the faith, worſhip, conſtitution, and diſcipline of the church of Rome, the churches of England and Scotland, the Lutheran and Calviniſtical churches on the continent of Europe, as well as of the various ſects which have ariſen in theſe kingdoms during the courſe of the laſt and preſent centuries. There is, however, one church which boaſts of a very high antiquity, and is certainly ſpread over a larger extent of country than all the other churches that we have mentioned, of which the account given in the Encyclopædia is exceedingly defective. Our readers will perceive that the church to which we allude is

1
The Greek church.

The Greek CHURCH, which comprehends in its boſom (A) a conſiderable part of Greece, the Grecian iſles, Wallachia, Moldavia, Egypt, Abyſſinia, Nubia, Lybia, Arabia, Meſopotamia, Syria, Cilicia, and Paleſtine, which are all under the juriſdiction of the patriarchs of Conſtantinople, Alexandria, Antioch, and Jeruſalem. If to theſe we add the whole of the Ruſſian empire in Europe, great part of Siberia in Aſia, Aſtracan, Caſan, and Georgia—it will be evident that the Greek church has a wider extent of territory than the Latin, with all the branches which have ſprung from it; and that it is with great impropriety that the church of Rome is called by her members the *catholic* or univerſal church. That in theſe widely diſtant countries the profeſſors of Chriſtianity are agreed in every minute article of belief, it would be raſh to aſſert; but there is certainly ſuch an agreement among them with reſpect both to faith and to diſcipline, that they mutually hold communion with each other, and are in fact but one church.

As the Greek church has no public or eſtabliſhed articles, like thoſe of the churches of England and Scotland, we can collect what is its doctrine only from its creed, from the councils whoſe decrees it receives

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(A) *King's Rites and Ceremonies of the Greek Church*—*Bruce's Travels to the Source of the Nile*—and *Lobo's Voyage to Abyſſinia*.

2
The faith of that church.

(b), from the different offices in its liturgies, and from the catechiſms which it authoriſes to be taught. "The doctrine of the Trinity, and the articles of the Nicene and Athanaſian creeds, are received by the Greeks in common with other Chriſtians. In one particular, indeed, they differ from the other churches of Europe, whether Romiſh or reformed. They believe, that the Holy Spirit proceeds from the Father only, and not from the Father and the Son; and in defence of this opinion they appeal to eccleſiaſtical hiſtory, the acts of councils, the writings of the fathers, ancient manuſcripts, and eſpecially to a copy of the creed of Conſtantinople, engraven on two tables of ſilver, and hung up in the church of St Peter at Rome by order of Leo III. Of the Nicene or Conſtantinopolitan creed, therefore, as it is received by them, the eighth article runs in theſe words; 'I believe in the Holy Ghoſt, the Lord and Giver of life, who proceedeth from the FATHER, and with the Father and the Son together is worſhipped and glorified:' And the correſponding article of the Athanaſian creed is of courſe, "The Holy Ghoſt is of the FATHER, neither made, nor created, nor begotten, but proceeding †."

† *Dallaway's Conſtantinople, Antient and Modern*, and *King's Rites and Ceremonies*, &c.

3
It admits of pictures, but not of graven images.

Though the biſhops and clergy of the Greek church abhor the uſe of images, which they pretend to be one cauſe of their ſeparation from the ſee of Rome, they admit into their churches the pictures of ſaints to inſtruct, they ſay, the ignorant, and to animate the devotion of others. This practice they conſider as by no means contrary to the ſecond commandment of the decalogue, which, according to them, prohibits only the worſhipping of ſuch idols as the Gentiles believed to be gods; whereas their pictures, being uſed merely as remembrancers of Chriſt and the ſaints, have written on each of them the name of the perſon whom it is meant to repreſent. Dr King aſſures us that the more learned of the Ruſſian clergy would willingly allow no repreſentation whatever of God the Father; and that, during the reign of Peter the Great, the ſynod not only cenſured the uſe of ſuch pictures in churches, but petitioned the emperor that they might be everywhere taken down. Peter, however, though he fully concurred in opinion with the ſynod, thought this a meaſure for which the minds of his ſubjects were not ripe, and dreaded, that if carried into execution it would occaſion a general inſurrection. Such pictures, therefore, though not more impious than abſurd, are ſtill in uſe; and in many churches, as well ancient as modern, the figure of Daniel's *Ancient of Days*, together with that of *Chriſt* and a *dove*, are painted in one group to ſignify the Holy Trinity. Nay, when our author was in St Peterſburg, not thirty years ago, there was in the church of St Nicholas the picture of an old man holding a globe, and ſurrounded with angels, on which GOD THE FATHER was inſcribed; and we have not heard that the picture has been ſince taken down.

4
Invocatic of ſaints.

In the Greek as well as in the Roman church, the invocation of ſaints is practiſed, but they are not invoked in either as deities, but merely as interceſſors with the Supreme God, "it being more modeſt (ſay the Greeks), as well as more available, to apply to them to intercede with God, than to addreſs ourſelves immediately to the Almighty." Plauſible as this reaſoning may at firſt ſight appear, it aſcribes to the ſaints the divine attribute of ubiquity, and is likewiſe in direct contradiction to the doctrine of St Paul, who hath taught us, that as "there is one God, ſo there is but one mediator between God and man, the man Chriſt Jeſus."

5
Prayers f the dead

The Greek church, at the celebration of the Lord's Supper, commemorates the faithful departed, and even prays for the remiſſion of their ſins; but ſhe allows not of purgatory, nor pretends to determine dogmatically concerning the ſtate or condition of departed ſouls. She muſt, however, believe that no final judgment is paſſed upon the great body of mankind (c) till the conſummation of all things, otherwiſe ſuch prayers could not be offered without abſurdity; and in this part of her doctrine ſhe is certainly countenanced by all the writers of the primitive church, if not by ſome paſſages of the ſacred ſcriptures.* The practice of praying for the dead is loudly condemned in every Proteſtant country, and yet there is no Chriſtian who does not in effect pray for his departed friends. This may appear a paradox, but it is an obvious and a certain truth; for where is the man who believes in a general judgment, and does not *wiſh* that his deceaſed wife, or parent, or child, or friend, "may find mercy of the Lord in that day?" Such a wiſh is the eſſence of a prayer; which conſiſts not of the ſounds in which our ſentiments are cloathed, but in the aſpirations of a devout heart.

* *Matth.* xxv. 19, —31—; 2 *Tim.* i. iv. 8.

6
Grants 1 indulgei cies.

Supererogation, with its conſequent indulgencies and diſpenſations, which were once ſo profitable, and afterwards ſo fatal to the intereſts of the court of Rome, are utterly diſallowed in the Greek church, which likewiſe lays no claim to the character of infallibility. She is indeed like ſome other churches, very inconſiſtent on this laſt topic; for whilſt ſhe pretends not to an abſolute exemption from error, her clergy ſeem to conſider their own particular mode of worſhip as that which alone is acceptable to God.

7
Predeſti tion.

Predeſtination is a dogma of the Greek Church, and a very prevailing opinion amongſt the people of Ruſſia; "and I muſt do the juſtice (ſays Dr King) to thoſe who have written upon it, eſpecially the lateſt authors of that country, to ſay that they have treated it, as depending on the attribute of preſcience in the divine nature, with a much better kind of logic than that with which ſuch points are generally diſcuſſed." As our author has not given us the reaſoning of the Ruſſian doctors on this difficult ſubject, we cannot hazard any opinion of our own on the ſoundneſs of their logic; but from the ſtate of ſcience in that vaſt empire, as it was repreſented to us by an abler judge than he, we doubt of its being entitled to the praiſe which he beſtows on it. (See Russia, n° 104. *Encycl.*)

(b) In the Greek church ſeven general councils are received, and nine provincial ones. The ſeven general councils are, 1. The council of Nice, held in the year 325, under Conſtantine. 2. The firſt council of Conſtantinople, held A. D. 381, under Theodoſius the Great. 3. The council of Epheſus, A. D. 431, in the reign of Theodoſius Minor. 4. The council of Calcedon, A. D. 451, in the reign of Marcian. 5. The ſecond council of Conſtantinople, A. D. 553, in the reign of Juſtinian. 6. The third council of Conſtantinople in Trull, A. D. 680, in the reign of Conſtantine Pagonatus. 7. The ſecond council of Nice, A. D. 787.

(c) We ſay the great body of mankind, becauſe ſhe doubtleſs believes that Enoch, Elias, and thoſe ſaints who roſe with our Saviour, have been already judged, and now enjoy their reward in heaven.

8
even ſa-
raments.

In the Greek church there are ſeven *ſacraments*; or, as they are there termed, *myſteries*, viz. *baptiſm*; the *chriſm*, or baptiſmal unction; the *euchariſt*; *confeſſion*; *ordination*; *marriage*; and the myſtery of *the holy oil*, or *euchelaion*. By the Greeks a myſtery is defined to be "a ceremony or act appointed by God, in which God giveth or ſignifieth his grace; and of the ſeven which they celebrate, four are to be received by all Chriſtians, viz. *baptiſm*, the *baptiſmal unction*, the *euchariſt*, and *confeſſion*. Of theſe, *baptiſm* and the *euchariſt* are deemed the chief; and of the other three none, not even the *euchelaion*, is conſidered as obligatory upon all.

With reſpect to baptiſm, we know not that they hold any peculiar opinions. They conſider it indeed as ſo abſolutely neceſſary to ſalvation, that in caſes of extremity, when a prieſt or deacon cannot be had, it may be adminiſtered by a midwife or any other perſon, and is not to be repeated on any occaſion whatever. In this opinion, as well as in the practice founded on it, they are in perfect harmony with the church of Rome, which, as every perſon knows, has for many ages allowed the validity of lay baptiſm in caſes of neceſſity. The Portugueſe Jeſuits, who in the laſt century viſited Abyſſinia in the capacity of miſſionaries, have maintained that once every year, all grown people are in that country baptized: but Mr Bruce has ſhown, by the moſt incontrovertible evidence, that this was a mere fiction, invented to throw odium upon what the church of Rome calls the eaſtern ſchiſm, and abhors perhaps more than paganiſm itſelf.

9
aily ſer-
ice of the
hurch,
10
ntricate
nd tedious,

The daily ſervice of the Greek Church is ſo long and ſo complicated, that it is impoſſible for us to give an adequate account of it, without ſwelling this article far beyond its due proportion. Of this the reader will be convinced, when he is informed that the ſeveral books containing the church ſervice for all the days in the year, amount to more than twenty volumes in folio, beſides one large volume called *the regulation*, which contains the directions how the reſt are to be uſed.

The four goſpels make one volume by themſelves; and whenever the goſpel is read in any ſervice, the deacon exclaims; "Wiſdom, ſtand up. Let us hear the holy goſpel." The prieſt then ſaith, "The leſſon from the goſpel according to St Matthew, St Mark, &c." The deacon ſays again, "Let us ſtand." The choir, at the beginning and end of the goſpel, always ſays, "Glory be to thee, O Lord, glory be to thee." From the old teſtament and the epiſtles extracts only are uſed in the ſervice, and when they are to be read, the deacon calls out, "Attend."

The ſervice of this church, as it now ſtands, and was at firſt drawn up in writing, is calculated for the uſe of monaſteries; and when it was afterwards applied to parochial churches, many of the offices or forms, which were compoſed for different hours of the day and night, were uſed as one ſervice, without the ſlighteſt alteration being made to avoid repetitions. Something of this kind has taken place in the church of England, where the matins, the litany, and the communion, which were formerly three diſtinct ſervices, read at different times of the day, are now run into one ſervice; which by thoſe not accuſtomed to it is therefore deemed long, as well as deformed by needleſs repetitions.

11
Begins in
the evening.

The ſervice of every day, whether it has a vigil or not, begins in the evening of what we would call the preceding day, as among the Jews; and for the ſame reaſon, becauſe it is ſaid in the Moſaic account of the creation, that "the evening and the morning were the firſt day." The ſeveral ſervices, according to the original or monkiſh inſtitution, are, 1. *The veſpers*, which uſed to be celebrated a little before ſun-ſet; 2. *The after veſpers*, anſwering to the *completorum* of the Latin church, which uſed to be celebrated after the monks had ſupped, and before they went to bed; 3. *The meſonyecticon*, or midnight ſervice; 4. *The matins* at break of day, anſwering to the *laudes* of the Romiſh church; 5. The *firſt hour* of prayer, or *prima*, at ſun-riſe; 6. The *third hour*, or *tertia*, at the third hour of the day; 7. The *ſixth hour*, or *ſexta*, at noon; 8. The *ninth hour*, or *nona*, in the afternoon at the ninth hour of the day. Theſe are called the canonical hours; but it is to be obſerved, that the *after-veſpers* were not added till a late period, before which the reaſon aſſigned for the number of ſervices being ſeven, was, that David ſaith, "Seven times a day will I praiſe thee." When all the pſalms and hymns were ſung, theſe daily ſervices could not poſſibly have been performed in leſs than twelve or fourteen hours. In the church of Ruſſia, and probably in other branches of the Greek church, there are at preſent but three ſervices in the day: the *ninth hour*, the *veſpers*, and the *after veſpers* making one; the *meſonyecticon*, the *matins*, and *prima*, another; and the *third* and *ſixth hour*, with the *communion*, the laſt. In all the ſervices, except the communion, prayers and praiſes are offered to ſome ſaint, and to the Virgin Mary, almoſt as often as to God; and in ſome of the ſervices, after every ſhort prayer uttered by the deacon or the prieſt, the choir chaunts, "Lord have mercy upon us," thirty, forty, or fifty times ſucceſſively.

Though the number of ſervices is the ſame every day, the ſervices themſelves are conſtantly varying in ſome particular or other, as there is not a day which, in the Greek Church, is not either a faſt or a feſtival. Beſides the ſaints, whoſe feſtivals are marked in the calendar, and who are ſo very numerous that there are more than one for every day in the year, there are other ſaints and feſtivals, to which ſome portion of the ſervice for every day of the week is appropriated. Thus, Sunday is dedicated to the reſurrection; Monday, to the angels; Tueſday, to St John Baptiſt; Wedneſday, to the virgin and the croſs; Thurſday, to the apoſtles; Friday, to the paſſion of Chriſt; and Saturday, to the ſaints and martyrs. For theſe days there are particular hymns and ſervices, in two volumes folio, to which there is a ſupplement, containing ſervices for the ſaints and feſtivals, as they occur in the calendar throughout the year. Theſe different ſervices are mixed together, and adjuſted by the directions contained in the book of *regulation*; and it is the difficulty of this adjuſtment which makes the public worſhip of the Greek Church ſo very intricate, that, as was ſaid of the ſervice of the Engliſh church before the Reformation, "there is more buſineſs to find out what ſhould be read, than to read it when found out."

We have obſerved, that the Greeks have no peculiar

12 Mode of adminiſtering baptiſm.

opinions reſpecting the nature of baptiſm; but the rites and ceremonies with which that ordinance is adminiſtered will appear to our unlearned readers very extraordinary. On the day that a woman is delivered, the prieſt goes to the houſe, and uſes a form of prayer for her and for her child. On the eighth day the child ſhould be regularly carried to the church, where the prieſt having ſigned it with the ſign of the croſs on the forehead, on the mouth, and on the breaſt, offers up for it a prayer, in which he firſt gives it a name, commonly the name of the ſaint for that day in the calendar; he then takes it from the midwife, and ſtanding before the picture of the bleſſed virgin, he makes the ſign of the croſs with the infant, uttering a kind of hymn in honour of the Virgin, and of Simeon, who held in his boſom the Saviour of our ſouls. He then diſmiſſes the company with an exhortation not to delay the baptizing of the infant ſhould it appear in danger of death before the regular time for its baptiſm.

On the fortieth day after her delivery, the mother ſhould attend the church to be purified, and carry the child again to be preſented, the perſon who is to be ſponſor being preſent. Upon their arrival at the church door, the prieſt utters ſome pious exclamations; and then, the mother holding the child in her arms and bowing down her head, he makes the ſign of the croſs upon her and the child, and laying his hand upon its head, he prays, that the woman may be cleanſed from every ſin, and from every defilement, and that the child may be ſanctified and endued with underſtanding, with wiſdom, and with gentleneſs of manners. He then ſigns it again, and again prays for it, for its parents, and for its ſponſor; after which, if it has been privately baptized, he takes it in his arms, and makes with it the ſign of the croſs before the door of the church, ſaying, "N. N. the ſervant of God, enters into the church in the name of the Father, and of the Son, and of the Holy Ghoſt, now and forever, even unto ages of ages. Amen." He then carries the child into the church, ſaying, "He ſhall go into thine houſe, and ſhall worſhip toward thy holy temple;" and advancing into the middle of the church, he ſays, "In the midſt of thy church ſhall he praiſe thee." Then if the child be a boy, he carries him within the rails of the altar; but if a girl, only to the door, and ſays, "*Nunc dimittis*(D);" after which he delivers it to the ſponſor, who makes three reverences, and retires.

This is called the preſentation of the child in the temple, and can only be performed after it has been baptized. In the detail we have given, we have ſuppoſed that it was baptized privately before the purification of the mother, which is now indeed commonly the caſe. Such baptiſm, however, is not regular, being allowed only in caſes of neceſſity, and when it has not taken place, the mother and child are diſmiſſed as ſoon as ſhe is purified, and return at ſome other time, not fixed, in order that the child may be publicly baptized.

Previous to baptiſm, the child, though not two months old, muſt be ſolemnly initiated into the church as a catechumen (See CATECHUMEN *Encycl.*). By thoſe whoſe religion is a reaſonable ſervice, ſuch initiation of an infant will be conſidered as a very idle ceremony; and the rites with which it is performed are not well calculated to give it even a fictitious importance. At the door of the church the prieſt unties the girdle of the infant; takes off all his clothes but one looſe garment; turns him towards the eaſt with his head uncovered, his feet naked, and his hands held down; blows thrice in his face; ſigns him thrice with the ſign of the croſs on the forehead, and on the breaſt, and lays his hand upon his head, praying that his "*ancient* error may be put away from him, that his heart may be filled with faith, hope and charity; and that he may walk in the ways of God's commandments." The prieſt then four times exorciſes the infant, commanding Satan in the firſt exorciſm to "tremble, depart, and flee from Chriſt's creature, nor dare to return again, nor dare to lurk concealed within him, or to meet him or to meditate againſt him, either in the evening or the morning, at midnight, or at noon day." In the laſt exorciſm he blows thrice upon the child's mouth, upon his forehead, and upon his breaſt; ſaying, each time, "Drive away from him every evil and unclean ſpirit that lurks in him, and hath made itſelf a neſt in his heart." The child is now become a catechumen, and, being turned to the weſt uncovered, without ſhoes, and his hands lifted up, the prieſt repeatedly aſks him, if he *renounces*, and *has* renounced the Devil and all his works? and receiving from the ſponſor the proper anſwer, he ſays, "blow and ſpit upon him;" and having blown and ſpit upon the catechumen, he turns him to the eaſt, and holding down his hands, aſks him repeatedly if he be joined to Chriſt, and if he believes in him? The catechumen or his ſponſor replies to each queſtion, that he is, and has been, joined to Chriſt; and as a proof of his faith he repeats, from beginning to end, the Nicene creed. After a repetition of the formerly repeated queſtions and anſwers, the prieſt prays that the catechumen may be called to God's holy ſanctification, and receive the grace of God's holy baptiſm.

Baptiſm may be celebrated immediately after the candidate has been made a catechumen, or on any ſubſequent day at no great diſtance. In the firſt part of the form there is not much that is ſingular, or with which every ſcholar is not acquainted. After praying that the water may be ſanctified, in terms differing little from thoſe which are uſed in the moſt reſpectable Proteſtant churches, the prieſt dips his fingers in it, ſigns it thrice with the ſign of the croſs; and then blowing upon it, ſays three times, "Let every adverſe power be confounded under the ſign of the croſs." He then ſolemnly exorciſes it of the dæmon of darkneſs and all evil ſpirits; and prays, that "the perſon to be baptized therein may put off the old man, which is corrupt after the luſt of fraud, and may put on the new man after the image of Him that made him." After this, he blows thrice into a veſſel of oil of olives held by the deacon, ſigns it thrice with the ſign of the croſs; and prays fervently, that it may "become to thoſe who are anointed with faith, and are partakers thereof, the unction of incorruption, the armour of righteouſneſs, the renewing of ſoul and body, for turning aſide all machinations

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(D) We quote the words of Dr King. Is it poſſible that in the Greek Church Latin hymns are uſed, or that Greek hymns have Latin deſignations?

hurch.

nations of the devil, and for deliverance from all evil." He then ſings allelujah thrice with the people, and pours the oil on the top of the water; and making three croſſes with it, ſays aloud, "Bleſſed be God, who enlighteneth and ſanctifieth every man that cometh into the world, now and forever, even unto ages of ages." The perſon to be baptized is then preſented; and the prieſt, taking ſome of the oil with two fingers, and making the ſign of the croſs on his forehead, on his breaſt, and betwixt his ſhoulders, ſays, "N the ſervant of God is anointed with the oil of gladneſs, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and forever, even unto ages of ages. Amen." He then ſigns him on the breaſt and the middle of the back, ſaying, "For the healing of his ſoul and body;" then on the ears, ſaying, "For hearing the faith;" then on the palms of the hands, ſaying, "Thy hands have made me and faſhioned me;" then on the feet, "That he may walk in the way of thy commandments." After the whole body is thus anointed, the prieſt baptizes him, uſing the trine immerſion; which is unqueſtionably the moſt primitive manner. He takes the child in his arms, and holding him upright with his face towards the eaſt, he ſays, "N the ſervant of God is baptized (*dipping him the firſt time*), in the name of the Father, Amen; in the name of the Son (*dipping him again*), Amen; and of the Holy Ghoſt (*dipping him the third time*), Amen, now and for ever, even unto ages of ages. Amen." After the baptiſm, the prieſt wipes his hands, and with the people ſings thrice, from beginning to end, the 32d Pſalm; he then puts upon the baptized perſon a white garment; ſaying, "N the ſervant of God is clothed with the garment of righteouſneſs, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages (E)." He then prays that he may be delivered from the evil one, and all his inſidious ſnares; that he may be confirmed in the true faith; and that he may preſerve his ſoul in purity and righteouſneſs: and proceeds immediately to anoint him with the *Holy Chriſm*.

13
T bap-
tial
ch.im.

This chriſm is a very different thing from the oil with which he was anointed previous to baptiſm, and which was uſed in the conſecration of the baptiſmal water. It can be prepared only by a biſhop, and only on one day in the year, *viz.* Thurſday in Paſſion-week; and as the anointing with it is ſubſtituted in place of the apoſtolical rite of laying on hands, called *confirmation* in the weſtern churches, great quantities of it are of courſe prepared at once, and diſtributed through the different churches of each dioceſe. The chriſm conſiſts of the following ingredients, which in different proportions are all boiled together, and afterwards ſolemnly conſecrated by the biſhop: Fine oil (we ſuppoſe of olives), white wine, ſtyrax calamita (F), palm-dew, roſe-flowers, black palm-gum, Baſil-gum, marjoram, thick and thin oil of nutmegs in very different quantities, oil of cinnamon, oil of cloves, lignum Rhodii, oil of oranges, oil of marjoram, oil of lavender, oil of roſemary, eſſence of roſemary, cedar, black balſam of Peru, ſandarac, whiteſt maſtic, and Venice turpentine. With this holy mixture the baptized perſon is anointed, the prieſt making with it the ſign of the croſs on his forehead, on his eyes, his noſtrils, his mouth, both ears, his breaſt, his hands, and his feet; ſaying at each part, "The ſeal of the gift of the Holy Ghoſt. Amen." Then with the ſponſor and the child he goes thrice round the font, turning from the right to the left; the choir, in the mean time, ſinging, "As many of you as are baptized unto Chriſt have put on Chriſt, allelujah."

Church.

Seven days after this ceremony is performed, the child is again brought to the church; when the prieſt, after praying for him, unties his girdle and linen clothes, waſhes him with clean water, and, ſprinkling him, ſays, "Thou haſt been juſtified, enlightened, ſanctified, in the name of our Lord Jeſus Chriſt, and with the Spirit of our God." Then taking a new ſponge moiſtened with water, he waſhes his face, breaſt, &c.; ſaying, "Thou haſt been baptized, enlightened, anointed, ſanctified, waſhed, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and for ever, even unto ages of ages. Amen."

14
The tonſure.

The laſt ceremony appended to baptiſm is that of the tonſure, or ſhaving the head of the child in the form of the croſs. At what time this rite crept into the church it would not be eaſy to diſcover. Some think it received its origin from the religious ceremonies of the Heathen, who certainly rounded the corners of their heads, and marred their beards at a very early period, in honor of their idols (See THEOLOGY, n° 155. *Encycl.*); and ſome pious, but fooliſh Chriſtians, eſteemed it highly commendable to transfer to the true God that worſhip, in a different form, which had been rendered by their anceſtors to falſe deities. Others will have the tonſure to typify the dedication of the perſon to the ſervice of God; the cutting off of the hair being always conſidered as a mark of ſervitude. Be theſe conjectures as they may, the prieſt, after the child is baptized, offers up for him ſeveral prayers, all alluding to the rite to be performed; and then cuts his hair croſs-wiſe, ſaying, "N the ſervant of God is ſhorn, in the name of the Father, and of the Son, and of the Holy Ghoſt, now and forever, even unto ages of ages. Amen."

We have given a full account of the manner in which the ſacrament of baptiſm is celebrated among the Greeks, that the reader may have ſome notion of the childiſh ſuperſtition of that church, with which certain zealous Proteſtants in England were very deſirous, at the beginning of this century, to form a union. There is no occaſion for dwelling ſo long upon their other offices. For the celebration of the Lord's Supper, they have three liturgies that are occaſionally uſed, *viz.* that of St Chryſoſtom, which is in ordinary daily uſe; that of St Baſil, uſed on particular days; and that of the *preſanctified*, as it is called, which is uſed on the Wedneſdays and Fridays during the great faſt before Eaſter. Between the liturgies of St Chryſoſtom and St Baſil there is no eſſential difference; and the office of the preſanctified

15
The Greeks have three communion-offices.

(E) The reader will perceive, that many of theſe rites and ceremonies are common to the Greek church and the church of Rome in the celebration of the ſacrament of baptiſm.

(F) We quote the words of Dr King, taking it for granted that our readers will pardon our not giving ourſelves much trouble to diſcover, on the preſent occaſion, what particular ſpecies or variety of the ſtorax he means by this deſignation. See STYRAX, *Encycl.*

by my hand conducteth thee N. archimandrite or hieromonachus, beloved of God, biſhop elect of the cities of N. N. which God preſerve !—Let us pray therefore for him, that the grace of the moſt Holy Spirit may come upon him." Then the prieſts ſay thrice, Lord have mercy upon us ;" and while the biſhops continue to hold the goſpel, the archbiſhop ſigns the newly conſecrated biſhop thrice with the ſign of the croſs, ſaying, " In the name of the Father, and of the Son, and of the Holy Ghoſt, now and forever, even unto ages of ages. Amen." Then all the biſhops putting their right hands on his head, the archbiſhop prays that he may be confirmed in the office of which they have judged him worthy, that his prieſthood may be rendered irreproachable, and that he himſelf may be made holy and worthy to be heard of God. After this, one of the aſſiſting biſhops reads a ſhort litany in a low voice, to be heard only by thoſe within the altar, and the other biſhops make the reſponſes. At the end of the litany the archbiſhop, laying his hand again upon the head of the newly conſecrated biſhop, prays in very decent and devout terms, that Chriſt will render him an imitator of himſelf, the true ſhepherd ; that he will make him a leader of the blind, a light to thoſe who walk in darkneſs, and a teacher of infants ; that he may ſhine in the world, and receive at laſt the great reward prepared for thoſe who contend boldly for the preaching of the goſpel. After this the paſtoral ſtaff is delivered to the new biſhop, with a very proper and ſolemn exhortation from the archbiſhop, to feed the flock of Chriſt committed to his care.

The laſt ſacrament of the Greek church is that of the holy oil or euchelaion, which is not confined to perſons *periculoſe ægrotantibus, et mortis periculo imminente*, like the extreme unction of the Romiſh church ; but is adminiſtered, if required, to devout perſons upon the ſlighteſt malady. Though this ordinance is derived from St James, chap. v. ver. 14, 15. it is by no means deemed neceſſary to ſalvation, or obligatory upon all Chriſtians ; and it is well that it is not, for ſeven prieſts are required to adminiſter it regularly, and it cannot be adminiſtered at all by leſs than three. The oil is conſecrated with much ſolemnity ; after which each prieſt, in his turn, takes a twig, and dipping it in the oil now made holy, anoints the ſick perſon croſs-wiſe, on the forehead, on the noſtrils, on the paps, the mouth, the breaſt, and both ſides of the hands, praying that he may be delivered from the bodily infirmity under which he labours, and raiſed up by the grace of Jeſus Chriſt.

26 The lavipedium.

In the Greek, as well as in the Latin church, there is a ſervice called the divine *lavipedium*, obſerved on the Thurſday of paſſion-week, in imitation of our Saviour's humility. At Conſtantinople, Jeſus Chriſt is, on this occaſion, perſonified by the Patriarch, and everywhere elſe by the biſhop of the dioceſe, and the twelve apoſtles by twelve regular prieſts, when a ludicrous conteſt ariſes who ſhall repreſent Judas ; for the name attaches for life. This office is performed at the weſt end of the church, where an arm chair is ſet at the bottom, facing the eaſt, for the biſhop ; and on each ſide are placed twelve chairs for the twelve prieſts, who are to repreſent the twelve apoſtles. The prayers and hymns uſed on this occaſion are extremely beautiful and appropriate ; and when the firſt goſpel, relating our Saviour's waſhing of his diſciples feet, begins to be read, the biſhop or patriarch riſes up, and takes off his pontifical veſtments, by himſelf without aſſiſtance. He then girds himſelf with a towel, and taking a baſon of water in his hand, kneels down and waſhes one foot of each prieſt, beginning with the youngeſt ; and after having waſhed it he kiſſes it. All this is done as the ſeveral circumſtances are read ; and when he comes to the laſt prieſt, who is ſuppoſed to repreſent Peter, that prieſt riſes up and ſaith, " Lord, doſt thou waſh my feet ?" &c. The biſhop anſwers in the words of our Saviour ; and having finiſhed the whole, puts on his garments again, and ſits down ; and as the ſecond goſpel is read (K), repeats the words of our Saviour, " Know ye what I have done unto you ?" &c. The office is certainly ancient, and if decently performed muſt be affecting.

Under the word PATRIARCHS (*Encycl.*) we have given a ſufficient account of the riſe of the patriarchates, as well as of the various degrees of rank and authority claimed by the biſhops of ſeveral other ſees in the Greek church. It may be proper to add here, that after the taking of Conſtantinople by Mohammed II. he continued to the patriarch of that city the ſame preſent which the Greek emperors had been accuſtomed to make, a paſtoral ſtaff, a white horſe, and four hundred ducates in gold. To the Greek church and the maintenance of its clergy he left indeed ample revenues, which they have gradually ſacrificed to their inconſtancy, their ambition, and their private jealouſy. Still, however, the patriarch of Conſtantinople fills a very lucrative and high office. " Beſides the power of nominating the other three patriarchs, and all epiſcopal dignitaries (ſays Mr Dallaway), he enjoys a moſt extenſive juriſdiction, compriſing the churches of Anatolia, Greece, Wallachia, Moldavia, and the iſlands of the Archipelago. Since the cloſe of the ſixteenth century, the Ruſſian church has claimed a juriſdiction independent of the ſee of Conſtantinople ; though appeals have been made to that ſee in caſes of extraordinary importance. The influence of the patriarch with the Porte is very extenſive, as far as his own nation is concerned. His memorials are never denied ; and he can, in fact, command the death, the exile, impriſonment for life, depoſition from offices, or pecuniary fine, of any Greek whom he may be inclined to puniſh with rigour, or who has treated his authority with contempt. On the death of the patriarch the moſt eager competition is exerted to fill the vacant throne ; which, as it is obtained by bribery and intrigue, is of courſe a very unſtable ſeat to the ſucceſsful candidate, ſhould another offer to accept the appointment at a lower ſalary." For a fuller account of the doctrines, diſcipline, and worſhip of the Greek church at preſent, we refer the reader to *King's Rites and Ceremonies of the Greek Church in Ruſſia*, and to *Dallaway's Conſtantinople ancient and modern* (publiſhed in 1797) ; from which two works this abſtract has been moſtly taken.

CHURCH *Creek Town*, in Dorcheſter co. Maryland, lies at the head of Church creek, a branch of Hudſon river, 7 miles S. weſterly from Cambridge. —*Morse*.

CHURCH

(K) The firſt goſpel is John xiii. 3—12. The ſecond goſpel is John xiii. 12—18.

CHURCH HILL, a village in Queen Anne's co. Maryland, at the head of S. E. Creek, a branch of Cheſter river; N. W. of Bridgetown, and N. E. of Centreville 8 miles, and 85 S. W. from Philadelphia. N. lat. 40. 9. W. long. 75. 53 —*ib.*

CHURCH HILL, FORT, in New N. Wales, ſtands at the mouth of Seal river on the E. ſide of Hudſon bay; 120 miles N. N. E. of York fort. N. lat. 48. 58. W. long. 94. 13.—*ib.*

CHURCHILL *River* in New South Wales, runs N. eaſterly into the W. ſide of Hudſon bay, at Church Hill fort, in lat. 58. 57. 32. N. long. 94. 12. 30. W.—*ib.*

CHURCHTOWN, a village, ſo called, in the N. E. part of Lancaſter co. Pennſylvania, about 20 miles E. N. E. of Lancaſter, and 50 W. N. W. of Philadelphia. It has 12 houſes, and an Epiſcopal church; and in the environs are two forges, which manufacture about 450 tons of bar iron annually.—*ib.*

CHUSAN-ISLANDS, a cluſter of ſmall iſlands on the eaſt coaſt of China, which were viſited by Lord Macartney in his courſe to Pekin. Moſt of theſe iſlands ſeem to be hills riſing regularly out of the ſea, and rounded at top, as if any points or angles exiſting in their original formation had been gradually worn off into a globular and uniform ſhape. Many of them, though cloſe to each other, are divided by channels of great depth. They reſt upon a foundation of grey or red granite, ſome part reſembling porphyry, except in hardneſs. They were, certainly, not formed by the ſucceſſive alluvion from the earth brought into the ſea by the great river at whoſe mouth they are ſituated, like the numerous low and muddy iſlands at the mouth of the Po, and many others; but ſhould rather be conſidered as the remains of part of the continent thus ſcooped and furrowed, as it were, into iſlands, by the force of violent torrents carrying off, further into the ſea, whatever was leſs reſiſtible than the rocks juſt mentioned. Some of them wore a very inviting aſpect; one in particular, called Poo-too, is deſcribed as a perfect paradiſe. This ſpot was choſen, no doubt, for its natural beauties, and afterwards embelliſhed, by a ſet of religious men, who, to the number of three thouſand, poſſeſs the whole of it, living there in a ſtate of celibacy. It contains four hundred temples, to each of which are annexed dwelling houſes and gardens for the accommodation of thoſe monks. This large monaſtery, as it may be called, is richly endowed, and its fame is ſpread throughout the empire.

The Engliſh Eaſt India Company had once a factory at Chuſan, the principal of theſe iſlands, from which they were many years ago interdicted. This, according to the account of a Chineſe merchant who remembered the factory, was not occaſioned by any offence given by the Engliſh, but by the avarice of the officers governing at Canton, who draw large ſums from the accumulation of foreign trade in that port. Perhaps, too, the exceſſive jealouſy of the Chineſe government might fancy danger in the unreſtrained communication between foreigners and the ſubjects of that empire in ſeveral of its ports at the ſame time.

Ting-hai, the chief town of Chuſan, reſembles Venice, but on a ſmaller ſcale. It is ſurrounded, as well as interſected, by canals, over which are thrown ſteep bridges, aſcended by ſteps like the Rialto. The ſtreets are narrow and paved with ſquare flat ſtones; but the houſes, unlike the Venetian buildings, are low and moſtly of one ſtory. The ornaments of theſe buildings are confined chiefly to the roofs, on the ridges of which are uncouth figures of animals in clay, ſtone, or iron. The town is full of ſhops, containing chiefly articles of clothing, food, and furniture, diſplayed to full advantage. Even coffins are painted in a variety of lively and contraſting colours. The ſmaller quadrupeds, including dogs, intended for food, are expoſed alive for ſale, as well as poultry, and fiſh in tubs of water with eels in ſand. When the gentlemen belonging to the embaſſy were at Ting-hai, they were ſtruck with the number of places where tin-leaf and ſticks of odoriferous wood were ſold for burning in the temples, which indicated no ſlight degree of ſuperſtition in the people. Superſtition, however, made them not idle; for throughout the whole place there was a quick and active induſtry. Men paſſed buſily through the ſtreets, while not an individual was ſeen aſking alms; and the women were employed in the ſhops. At Chuſan, the number of valuable harbours, or places of perfect ſecurity for ſhips of any burden, is almoſt equal to the number of iſlands. This advantage, together with that of their central ſituation, in reſpect to the eaſtern coaſt of China, and the vicinity of Corea, Japan, Leoo-keoo, and Formoſa, attract conſiderable commerce, eſpecially to Ning-poo, a city of great trade in the adjoining province of Che-chiang, to which all the Chuſan iſlands are annexed. From one port in that province twelve veſſels ſail annually for copper to Japan.

According to Brooks, Chuſan is in N. Lat. 30. 0. and E. Long. 124. 0.

CIACICA, a juriſdiction in S. America, in Peru, ſubject to the archbiſhop of Plata, and 90 leagues diſtant from that city; abounding in cocoa, cattle, and ſome ſilver mines.—*Morſe.*

CIBOLA, or *Civola*, the name of a town in, and alſo the ancient name of, New-Granada, in Terra Firma, South-America. The country here, though not mountainous, is very cool; and the Indians are ſaid to be the whiteſt, wittieſt, moſt ſincere and orderly of all the aboriginal Americans. When the country was diſcovered, they had each but one wife, and were exceſſively jealous. They worſhipped water, and an old woman that was a magician; and believed ſhe lay hid under one of their lakes.—*ib.*

CICERO, a military townſhip in New-York, on the S. W. ſide of Oneida lake; and between it, the Salt lake, and the Salt ſprings.—*ib.*

CINALOA, called by ſome *Cinoleo*, a province in the audience of Galicia, in Old-Mexico, or New-Spain. It has the gulf of California on the W. the province of Culiacan on the S. and the kingdom of New-Mexico on the N. and E. From S. E. to N. E. it is about 100 leagues; and not above 40 where broadeſt. On the E. ſide it is bounded by the high craggy mountains, called Tepecſuan, 30 or 40 leagues from the ſea. It is well watered, its rivers abound with fiſh, and the air is ſerene and healthful. It abounds with all ſorts of fruit, and grain, and cotton. The natives are hardy and induſtrious, and manufacture cotton cloth, with which they clothe themſelves.—*ib.*

CINARA, or CYNARA, which we tranſlate *artichoke*, is, according to Profeſſor Beckmann, the name which was given by the ancients to a plant very different from the artichoke of our kitchen gardens, though he admits that they belong to the ſame genus. The proofs which he adduces for the truth of his opinion are too tedious to be introduced into this Work, eſpecially as they appear not to us to be abſolutely concluſive. We muſt therefore refer the reader to his Hiſtory of Inventions. The *cinara*, *carduus*, and *ſcolymus* (ſee Scolymus in this Supplement), were in his opinion ſpecies of the *thiſtle*, of which the *roots* and young *ſhoots*, as well as the bottom of the *calyx* of the laſt, were eaten. He has proved indeed, he thinks, that the Greeks and Romans uſed the pulpy bottom of the calyx, and the tendereſt ſtalks and young ſhoots of many plants belonging to the thiſtle kind, in the ſame manner as we uſe artichokes and cardoons, but that theſe latter were unknown to them.

“ It appears probable (ſays he) that the uſe of theſe thiſtles, at leaſt in Italy and Europe in general, was in the courſe of time laid aſide and forgotten, and that the artichoke, when it was firſt brought to Italy from the Levant, was conſidered as a new ſpecies of food. It is undoubtedly certain that our artichoke was firſt known in that country in the 15th century. Hermolaus Barbarus, who died in 1494, relates that this plant was firſt ſeen at Venice in a garden in 1473, at which time it was very ſcarce. About the year 1466, one of the family of Strozza brought the firſt artichokes to Florence from Naples. Politian, in a letter in which he deſcribes the diſhes he found at a grand entertainment in Italy in 1488, among theſe mentions artichokes. They were introduced into France in the beginning of the 16th century, and into England in the reign of Henry VIII.”

The original country of the artichoke is unknown. Linnæus ſays that it grew wild in Narbonne, Italy, and Sicily, as the cardoon did in Crete; but our author has proved very ſufficiently, that with reſpect to both theſe facts the great botaniſt was miſinformed. The artichoke is certainly known in Perſia; but Tavernier ſays expreſsly, that it was carried thither, like aſparagus and other European vegetables of the kitchen garden, by the Carmelite and other monks: and that it was only in latter times that it became common.

CINCINNATI, a flouriſhing town in the territory of the U. S. N. W. of the Ohio, and the preſent ſeat of government. It ſtands on the N. bank of the Ohio, oppoſite the mouth of Licking river $2\frac{1}{2}$ miles S. W. of Fort Waſhington, and about 8 miles weſterly of Columbia. Both theſe towns lie between Great and Little Miami rivers. Cincinnati contains about 200 houſes; and is 82 miles N. by E. of Frankfort; 90 N. W. of Lexington, and 779 W. by S. of Philadelphia. N. lat. 39. 22. W. long. 85. 44.—*Morſe*.

CINCINNATUS, is the S. eaſternmoſt of the military townſhips of New-York ſtate. It has Virgil on the W. and Salem, in Herkemer co. on the E. and lies on two branches of Tioughnioga river, a N. weſtern branch of the Chenango. The centre of the town lies 53 miles S. W. by W. of Cooperſtown, and 39 S. E. by S. of the S. E. end of Salt Lake. N. lat. 42. 30.

CINNABAR. See Chemistry in this Supplement, n° 91.

CIRCLE of Curvature, or circle of equicurvature, is that circle which has the ſame curvature with a given curve at a certain point; or that circle whoſe radius is equal to the radius of curvature of the given curve at that point.

Circles of Declination are great circles interſecting each other in the poles of the world.

Circle of Diſſipation, in optics. See Optics, *Encycl.* n° 253.

Circle Equant, in the Ptolemic aſtronomy, is a circle deſcribed on the centre of the equant. Its chief uſe is to find the variation of the firſt inequality.

Circles of Excurſion are little circles parallel to the ecliptic, and at ſuch a diſtance from it, as that the excurſions of the planets towards the poles of the ecliptic may be included within them; being uſually fixed at about 10 degrees.

Circles of Poſition, are circles paſſing through the common interſections of the horizon and meridian, and through any degree of the ecliptic, or the centre of any ſtar, or other point in the heavens; and are uſed for finding out the ſituation or poſition of any ſtar. Theſe are uſually ſix in number, cutting the equinoctial into 12 equal parts, which the aſtrologers call the *celeſtial houſes*, and hence they are ſometimes called *circles of the celeſtial houſes*.

CIRCULAR Lines, a name given by ſome authors to ſuch ſtraight lines as are divided by means of the diviſions made in the arch of a circle; ſuch as the ſines, tangents, ſecants, &c.

Circular Parts, called, from the uſe which he firſt made of them, *Napier's* circular parts, are the five parts of a right-angled or a quadrantal ſpherical triangle; they are the two legs, the complement of the hypothenuſe, and the complements of the two oblique angles.

Concerning theſe circular parts, Napier gave a general rule in his *Logarithmorum Canonis Deſcriptio*, which is this; “ The rectangle under the radius and the ſine of the middle part is equal to the rectangle under the tangents of the adjacent parts, and to the rectangle under the coſines of the oppoſite parts. The right angle or quadrantal ſide being neglected, the two ſides and the complements of the other three natural parts are called the *circular parts*, as they follow each other as it were in a circular order. Of theſe, any one being fixed upon as the middle part, thoſe next it are the adjacent, and thoſe fartheſt from it the oppoſite parts.”

This rule contains within itſelf all the particular rules for the ſolution of right-angled ſpherical triangles, and they were thus brought into one general comprehenſive theorem, for the ſake of the memory; as thus, by charging the memory with this one rule alone: All the caſes of right angled ſpherical triangles may be reſolved, and thoſe of oblique ones alſo, by letting fall a perpendicular, excepting the two caſes in which there are given either the three ſides, or the three angles. And for theſe a ſimilar expedient has been deviſed by Lord Buchan and Dr Minto, which may be thus expreſſed: “ Of the circular parts of an oblique ſpherical triangle, the rectangle under the tangents of half the ſum and half the difference of the ſegments at the middle part (formed by a perpendicular drawn from an angle to the oppoſite ſide), is equal to the rectangle under the tangents of half the ſum and half the difference of the oppoſite parts.” By the circular parts of an oblique ſpherical triangle are meant its three ſides and the ſupplements of its three angles. Any of theſe ſix being aſſumed as a middle part, the oppoſite parts are thoſe two of the ſame denomination with it, that is, if the middle part is one of the ſides, the oppoſite parts are the other two, and, if the middle part is the ſupplement of one of the angles, the oppoſite parts are the ſupplements of the other two. Since every plane triangle may be conſidered as deſcribed on the ſurface of a ſphere of an infinite radius, theſe two rules may be applied to plane triangles, provided the middle part be reſtricted to a ſide.

Thus it appears that two ſimple rules ſuffice for the ſolution of all the poſſible caſes of plane and ſpherical triangles. Theſe rules, from their neatneſs, and the manner in which they are expreſſed, cannot fail of engraving themſelves deeply on the memory of every one who is a little verſed in trigonometry. It is a circumſtance worthy of notice, that a perſon of a very weak memory may carry the whole art of trigonometry in his head.

CIRCULATING Decimals. See Decimals in this Supplement.

CIVIDAD REAL, the capital city of Chiapa, in New-Spain. Chilton, an Engliſhman, ſays the Indians called it Sacatlan, and that, in 1570, it contained about 100 Spaniſh inhabitants.—*Morse.*

Cividad Real, is the capital of the province of Guaira, in the E. diviſion of Paraguay.—*ib.*

CLAIR, St, a county in the territory N. W. of the Ohio; was laid off 27th April, 1790. Its boundaries are thus officially deſcribed: " Beginning at the mouth of the Little Michillimackinack river; running thence ſoutherly in a direct line to the mouth of the Little river above fort Maſſac, upon the Ohio river; thence with the Ohio to its junction with the Miſſiſſippi; thence up the Miſſiſſippi to the mouth of the Illinois river; and up the Illinois to the place of beginning, with all the adjacent iſlands of the ſaid rivers Illinois and Miſſiſſippi."—*ib.*

Clair, St, a fort in the territory N. W. of the Ohio, is ſituated 25 miles N. of fort Hamilton, on a ſmall creek which falls into the Great Miami; and 21 miles S. of fort Jefferſon.—*ib.*

Clair, St, *Lake*, lies about half way between lake Huron and lake Erie, in North America, and is about 90 miles in circumference. It receives the waters of the three great lakes, Superior, Michigan, and Huron, and diſcharges them through the river or ſtrait, called D'Etroit (which is in French, the Strait) into lake Erie. Its channel, as alſo that of the lake, is ſufficiently deep for veſſels of very conſiderable burden.—*ib.*

CLARE, a townſhip on St Mary's bay, in Annapolis co. Nova-Scotia. It has about 50 families, and is compoſed of woodland and ſalt marſh.—*ib.*

CLAREMONT, a townſhip in Cheſhire co. New-Hampſhire; on the E. ſide of Connecticut river, oppoſite Aſcutney mountain, in Vermont, and on the N. ſide of Sugar river; 24 miles S. of Dartmouth college, and 82 S. W. by W. of Portſmouth. It was incorporated in 1764, and contains 1435 inhabitants.—*ib.*

Claremont *Co.* in Camden diſtrict, S. Carolina, contains 2479 white inhabitants, and 2110 ſlaves. Stateſburg is the county town.—*ib.*

CLARENDON *Co.* the ſouthernmoſt in Camden diſtrict, S. Carolina, is about 30 miles long and 30 broad, and contains 1790 whites and 602 ſlaves.—*ib.*

Clarendon, a townſhip near the centre of Rutland co. Vermont, watered by Otter Creek and its tributary ſtreams; 14 or 15 miles E. of Fairhaven, and 44 N. E. of Bennington. It contains 1478 inhabitants. On the S. E. ſide of a mountain in the weſterly part of Clarendon, or in the edge of Tinmouth, is a curious cave, the mouth of which is not more than 2½ feet in diameter. In its deſcent, the paſſage makes an angle with the horizon of 35 or 40 degrees; but continues of nearly the ſame diameter through its whole length, which is 31½ feet. At that diſtance from the mouth, it opens into a ſpacious room, 20 feet long, 12½ wide, and 18 or 20 feet high. Every part of the floor, ſides and roof of this room appear to be a ſolid rock, but very rough and uneven. The water is continually percolating through the top, and has formed ſtalactites of various forms; many of which are conical, and ſome have the appearance of maſſive columns. From this room there is a communication by a narrow paſſage to others equally curious.—*ib.*

CLARKE, a new county of Kentucky between the head waters of Kentucky and Licking rivers. Its chief town is Wincheſter.—*ib.*

CLARKSBURG, the chief town of Harriſon co. Virginia. It contains about 40 houſes, a court-houſe, and gaol; and ſtands on the E. ſide of Monongahela river, 40 miles S. W. of Morgantown.—*ib.*

CLARKSTOWN, in Orange co. New-York, lies on the W. ſide of the Tappan Sea, 2 miles diſtant; northerly from Tappan townſhip, 6 miles, and from New-York city, 29 miles. By the ſtate cenſus of 1796, 224 of its inhabitants are electors.—*ib.*

CLARKSVILLE, the chief town of what was till lately called Tenneſſee co. in the ſtate of Tenneſſee, is pleaſantly ſituated on the E. bank of Cumberland river, and at the mouth of Red river, oppoſite the mouth of Muddy Creek. It contains about 30 houſes, a court-houſe and gaol, 45 miles N. W. of Naſhville; 220 N. W. by W. of Knoxville, and 940 W. by S. of Philadelphia. N. lat. 36. 25. W. long. 88. 57.—*ib.*

Clarksville, a ſmall ſettlement in the N. W. territory, which contained, in 1791, about 60 ſouls. It is ſituated on the northern bank of the Ohio, oppoſite Louiſville, a mile below the Rapids, and 100 miles S. E. of Poſt Vincent. It is frequently flooded, when the river is high, and inhabited by people who cannot, at preſent, find a better ſituation.—*ib.*

CLAVERACK, a poſt town in Columbia co. New-York, pleaſantly ſituated on a large plain, about 2½ miles E. of Hudſon city, near a creek of its own name. It contains about 60 houſes, a Dutch Church, a court-houſe, and a gaol. The townſhip, by the cenſus of 1791, contained 3262 inhabitants, including 340 ſlaves. By the ſtate cenſus of 1796, there appears to be 412 electors. It is 231 miles from Philadelphia.—*ib.*

CLERK's *Iſles*, lie S. W. from, and at the entrance of Behring's ſtraits, which ſeparate Aſia from America. They rather belong to Aſia, being very near, and S. S. W. from the head land which lies between, the ſtraits and the gulf of Anadir, in Aſia. They have their name in honor of that able navigator, Capt. Clerk, the companion of Capt. Cook. In other maps they are called St Andrea Iſles.—*ib.*

CLERMONT, a poſt town in Columbia co. New-York, 6 miles from Red Hook, 15 from Hudſon, 117 miles N. of New-York, and 212 from Philadelphia. The townſhip contains 867 inhabitants, incluſive of 113 ſlaves.—*ib.*

time that ambaſſadors appeared in coaches on a public ſolemnity was at the imperial commiſſion held at Erfurth in 1613, reſpecting the affair of Juliers.

In the hiſtory of France we find many proofs that at Paris, in the 14th, 15th, and even 16th centuries, the French monarchs rode commonly on horſes, the ſervants of the court on mules, and the princeſſes, together with the principal ladies, ſometimes on aſſes. Perſons of the firſt rank often ſat behind their equerry, and the horſe was often led by ſervants. Carriages, however, of ſome kind appear to have been uſed very early in France. An ordinance of Philip the Fair, iſſued in 1294 for ſuppreſſing luxury, and in which the citizens wives are forbid to uſe carriages *(cars)*, is ſtill preſerved. Under Francis I. or rather about 1550, ſomewhat later, there were in Paris for the firſt time only three coaches.

The oldeſt carriages uſed by the ladies in England were known under the now forgotten name of *whirlicotes*. When Richard II. towards the end of the 14th century, was obliged to fly before his rebellious ſubjects, he and all his followers were on horſeback; his mother only, who was indiſpoſed, rode in a carriage. This, however, became afterwards ſomewhat unfaſhionable, when that monarch's queen, Anne, the daughter of the Emperor Charles IV. ſhewed the Engliſh ladies how gracefully and conveniently ſhe could ride on a ſide-ſaddle. Whirlicotes were laid aſide, therefore, except at coronations and other public ſolemnities. Coaches were firſt known in England about the year 1580, and, as Stow ſays, were introduced from Germany by Fitzallen, earl of Arundel. In the year 1598, when the Engliſh ambaſſador came to Scotland, he had a coach with him. Anderſon places the period when coaches began to be in common uſe about the year 1605. The celebrated duke of Buckingham, the unworthy favourite of two kings, was the firſt perſon who rode with a coach and ſix horſes, in 1619. To ridicule this new pomp, the earl of Northumberland put eight horſes to his carriage.

Reſpecting the progreſs of luxury with regard to coaches, the reader will find much curious information in the firſt volume of Profeſſor Beckmann's Hiſtory of Inventions. It is perhaps one of the moſt entertaining articles in that very learned work. The author, however, with all his labour, has not been able to aſcertain the country in which coaches hung on ſprings were firſt uſed; but he ſeems inclined to give the credit of the invention to Hungary.

COATZACUALCO, a navigable river of Mexico, or New-Spain, which empties into the gulf of Mexico, near the country of Onohualco.—*Morſe*.

COBALT (ſee CHEMISTRY-*Index*, in this Supplement), is a valuable article to potters and dyers. To fit it for their uſe, it is firſt roaſted, and freed from the foreign mineral bodies with which it is united; it is then well calcined, and ſold either mixed or unmixed with fine ſand under the name of zaffer *(zaffera)*; or it is melted with ſiliceous earth and pot aſhes to a kind of blue glaſs called *ſmalt*, which when ground very fine is known in commerce by the name of *powder blue*. All theſe articles, becauſe they are moſt durable pigments, and thoſe which beſt withſtand fire, and becauſe one can produce with them every ſhade of blue, are employed above all for tinging cryſtal and for enamelling: for counterfeiting opaque and tranſparent precious ſtones, and for painting and varniſhing real porcelain and earthen and potters ware. This colour is indiſpenſably neceſſary to the painter, when he is deſirous of imitating the fine azure colour of many butterflies and other natural objects; and the cheaper kind is employed to give a bluiſh tinge to new-waſhed linen, which ſo readily changes to a diſagreeable yellow, though not without injury to the health, as well as to the linen.

Profeſſor Beckmann, in his *Hiſtory of Inventions*, gives the following account of the paint prepared from cobalt. "About the end of the 15th century cobalt appears to have been dug up in great quantity in the mines on the borders of Saxony and Bohemia, diſcovered not long before that period. As it was not known at firſt to what uſe it could be applied, it was thrown aſide as a uſeleſs mineral. The miners had an averſion to it, not only becauſe it gave them much fruitleſs labour, but becauſe it often proved prejudicial to their health by the arſenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then firſt took its riſe. At any rate I have never met with it before the beginning of the 16th century; and Matheſius and Agricola ſeem to have firſt uſed it in their writings. Friſch derives it from the Bohemian word *kow* which ſignifies *metal;* but the conjecture that it was formed from *cobalus*, which was the name of a ſpirit that, according to the ſuperſtitious notions of the times, haunted mines, deſtroyed the labours of the miners, and often gave them a great deal of unneceſſary trouble, is more probable; and there is reaſon to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, becauſe it thwarted them as much as the ſuppoſed ſpirit, by exciting falſe hopes and rendering their labour often fruitleſs. It was once cuſtomary, therefore, to introduce into the church-ſervice a prayer that God would preſerve miners and their works from *kobolts* and ſpirits.

" Reſpecting the invention of making an uſeful kind of blue glaſs from cobalt, we have no better information than that which Klotzſch has publiſhed from the papers of Chriſtian Lehmann. The former author of an hiſtorical work reſpecting the upper diſtrict of the mines in Miſnia, and a clergyman at Scheibenberg, collected with great diligence every information that reſpected the hiſtory of the neighbouring country, and died at a great age, in 1688. According to his account, the colour-mills at the time when he wrote were about a hundred years old; and as he began firſt to write towards the end of the thirty years war, the invention ſeems to fall about 1540 or 1560. He relates the circumſtance as follows, ' Chriſtopher Schurer, a glaſs-maker at Platten, a place which belongs ſtill to Bohemia, retired to Neudeck, where he eſtabliſhed his buſineſs. Being once at Schneeberg, he collected ſome of the beautiful coloured pieces of cobalt which were found there, tried them in his furnace; and finding that they melted, he mixed ſome cobalt with glaſs metal, and obtained fine blue glaſs. At firſt he prepared it only for the uſe of the potters; but in the courſe of time it was carried as an article of merchandize to Nuremberg, and thence to Holland. As painting on glaſs was then much cultivated in Holland, the artiſts there knew better how to appreciate this invention. Some Dutchmen therefore repaired to Neudeck, in order that they might learn the proceſs uſed in preparing this new paint. By great promiſes they perſuaded the inventor to remove to Magdeburg, where he alſo made glaſs from the cobalt of Schneeberg; but he again returned to his former reſidence, where he conſtructed a handmill to grind his glaſs, and afterwards erected one driven by water. At that period the colour was worth 7½ dollars per cwt. and in Holland from 50 to 60 florins. Eight colour-mills of the ſame kind, for which roaſted cobalt was procured in caſks from Schneeberg, were ſoon conſtructed in Holland; and it appears that the Dutch muſt have been much better acquainted with the art of preparing, and particularly with that of grinding it, than the Saxons; for the Elector, John George ſent for two colour-makers from Holland, and gave a thouſand florins towards the enabling them to improve the art. He was induced to make this advance chiefly by a remark of the people of Schneeberg, that the part of the cobalt which dropped down while it was roaſting contained more colour than the roaſted cobalt itſelf. In a little time more colour-mills were erected around Schneeberg. Hans Burghard, a merchant, and chamberlain of Schneeberg, built one, by which the eleven mills at Platten were much injured. Paul Nordhoff, a Frieſlander, a man of great ingenuity, who lived at the Zwittermill, made a great many experiments in order to improve the colour; by which he was reduced to ſo much poverty that he was at length forced to abandon that place, where he had been employed for ten years in the colour-manufactory. He retired to Annaberg, eſtabliſhed there in 1649, by the aſſiſtance of a merchant at Leipſic, a colour-manufactory, of which he was appointed the director; and by theſe means rendered the Annaberg cobalt of utility. The conſumption of this article, however, muſt have decreaſed in the courſe of time; for in the year 1659, when there were mills of the ſame kind at more of the towns in the neighbourhood of mines, he had on hand above 8000 quintals.' Thus far Lehmann."

Koſsler ſays, that the Bohemian cobalt is not ſo good as that of Miſnia, and that its colour is more like that of aſhes. We truſt, however, that the qualities of foreign cobalt ſhall ſoon be a matter of little importance to the Britiſh artiſt, as a rich mine of this mineral has lately been diſcovered near Penzance in Cornwal.

COBBESECONTE, or *Copſecook*, which in the Indian language ſignifies the land where ſturgeon are taken, is a ſmall river which riſes from ponds in the town of Winthrop, in the diſtrict of Maine; and falls into the Kennebeck within 5 miles of Nahunkeag Iſland, and 15 from Mooſe Iſland.—*Morse.*

COBEQUIT, or *Colcheſter River*, in Nova-Scotia, riſes within 20 miles of Tatamogouche, on the N. E. coaſt of Nova-Scotia; from thence it runs ſoutherly, then S. W. and W. into the E. end of the Baſin of Minas. At its mouth there is a ſhort bank, but there is a good channel on each ſide, which veſſels of 60 tons burden may paſs, and go 40 miles up the river. There are ſome ſcattered ſettlements on its banks.—*ib.*

COBEZA, or *Cobija*, an obſcure port and village in the audience of Los Charcos, in Peru, S. America. The place is inhabited by about 50 Indian families, and is the moſt barren ſpot on the coaſt. This is, however, the neareſt port to Lipes, where there are ſilver mines, and alſo to Potoſi, which is yet above 100 leagues diſtant, and that through a deſart country.—*ib.*

COBHAM, a ſmall town in Virginia, on the S. bank of James river oppoſite Jameſtown; 20 miles N. W. of Suffolk, and 8 or 9 S. W. of Williamſburgh.—*ib.*

COBHAM *Iſle*, mentioned by Captain Middleton, in the journal of his voyage for finding a N. E. paſſage. Its two extremities bear N. by E. and E. by N. in N. lat. 63. E. long. from Churchill, 3. 40. which he takes to be the *Brook Cobham* of Fox.—*ib.*

COBLESKILL, a new town, in the co. of Schoharie, New-York, incorporated March 1797.

COCALICO, a townſhip in Lancaſter co. Pennſylvania.—*ib.*

COCHECO, a N. W. branch of Piſcataqua river in New-Hampſhire. It riſes in the Blue Hills in Strafford co. and its mouth is 5 miles above Hilton's Point.—*ib.*

COCHABAMBA, a province and juriſdiction in Peru, 50 leagues from Plata, and 56 from Potoſi. Its capital of the ſame name is one of the richeſt, largeſt, and moſt populous in Peru, as it is the granary of the archbiſhoprick of Plata; and in ſome ſpots ſilver mines have been diſcovered.—*ib.*

COCKBURNE, a townſhip in the northern part of New-Hampſhire, Grafton co. on the E. Bank of Connecticut river, S. of Colebrooke.—*ib.*

COCKERMOUTH, a town in Grafton co. New-Hampſhire, about 15 miles N. E. of Dartmouth College. It was incorporated in 1766, and in 1775, contained 118 inhabitants; and in 1790, 373.—*ib.*

CODORUS, a townſhip in York co. Pennſylvania.—*ib.*

COEYMANS, a townſhip in Albany co. New-York, 12 miles below Albany. By the ſtate cenſus of 1796, 389 of its inhabitants are electors.—*ib.*

COFFEA, the COFFEE-TREE, is a plant which has been botanically deſcribed in the Encyclopædia Britannica, where ſome account is likewiſe given of the modes of cultivating it, as well as of the qualities of its fruit. Since that account, however, was publiſhed, two works have fallen into our hands, from which we deem it our duty to make ſuch extracts as may not only correct ſome miſtakes which we had committed, but alſo communicate uſeful information to the public.

In our former article we adopted the common opinion, that the coffee produced in Arabia is ſo greatly ſuperior to that which is raiſed everywhere elſe, that it is vain to think of cultivating the plant to any extent in the Weſt India iſlands. We are happy to find that this is a vulgar error. In the year 1783, when the cultivation of coffee was not ſo well underſtood in Jamaica as at preſent, ſome ſamples from that iſland were produced in London, and pronounced by the dealers to be equal to the very beſt brought from the Eaſt. "Two of the ſamples were equal to the beſt Mocha coffee, and two more of them ſuperior to any coffee to be had at the grocers ſhops in London, unleſs you will pay the price of *picked* coffee for it, which is two ſhillings per pound more than for that which they call the *beſt* coffee. All the reſt of the ſamples were far from bad coffee, and very little inferior, if at all, to what the grocers call *beſt* coffee*."

If this be ſo, it ſurely becomes the legiſlature of Great Britain to encourage the cultivation of coffee in the Weſt Indies, eſpecially as it thrives beſt in ſoil which is not fit for the ſugar-cane, and may be raiſed in conſiderable quantities by thoſe who are not able to ſtock a ſugar plantation. The encouraging every article which increaſes the intercourſe with our colonies is increaſing our commerce. The payment for all the ſtaples of the Weſt Indies is made in our manufactures; the ſale of which muſt increaſe in proportion to the numbers that are employed in the cultivation of what is bartered for them. Our Weſt India iſlands, without draining us of ſpecie or bullion, can ſupply us with many of thoſe very articles for which we are drained in other parts of the world, and particularly with coffee.

To give a detailed account of the introduction of the coffee-tree into the Weſt Indies, would ſwell this article to very little purpoſe. According to Boerhaave, a Dutch governor was the firſt perſon who procured freſh berries from Mocha, and planted them in Batavia; and in the year 1690 ſent a plant from thence to Amſterdam, which came to maturity, and produced thoſe berries which have ſince furniſhed all that is now cultivated in the Weſt Indies.

In 1714 a plant from the garden of Amſterdam was ſent by Mr Pancras, a burgomaſter, and director of the botanic garden, as a preſent to Louis XIV. which was placed in the garden at Marly. In 1718 the Dutch began to cultivate coffee in Surinam; in 1721 the French began to cultivate it at Cayenne; in 1727 at Martinico; and in 1728 the Engliſh began to cultivate it in Jamaica.

As it has been more cultivated in the French Weſt-India iſlands than in the Britiſh, it may be of importance to our coloniſts to be made acquainted with the practice of the French planters. Accordingly Dr Laborie, a royaliſt of St. Domingo, has lately publiſhed a volume for their inſtruction on this ſubject; in which are many judicious obſervations, the reſult of long experience, reſpecting the ſoil fit for a coffee-plantation; the various eſtabliſhments neceſſary; the cultivation of the coffee-tree through the ſeveral ſtages of its growth and duration; and the management and uſe of the negroes and cattle.

With reſpect to ſoil, it is a fact, ſays he, beyond contradiction, that low lands, and even the mountains near the champaign country, are leſs proper for the production of coffee, than lands which are high and at a diſtance from the ſea. The coffee-tree delights in a comparatively cool climate, and in an open and permeable virgin ſoil; and is hurt by the parching deſtructive air of the ſea. The ſoil on the mountains of St Domingo conſiſts generally of a bed of mould more or leſs deep; but which, for the production of coffee-trees, ought not to be leſs than four or five feet. If the declivity be gentle, the ſofteſt and moſt friable earth is preferable to all others; but in ſteep grounds a firm though not clayey ſoil, mixed with a proportion of gravel or ſmall ſtones, through which the water may find an eaſy way, is the moſt deſirable. The colour of the ground is of little conſequence, though ſuch as is ſomewhat reddiſh is generally to be preferred. With regard to expoſure, the north and weſt are the moſt eligible in low and hot ſituations, becauſe theſe expoſures are the cooleſt; and on the higheſt mountains the ſouth and eaſt are to be choſen, becauſe they are the hotteſt. On the whole, neither the higheſt nor the loweſt ſituations are the beſt, but thoſe which are conſiderably above the middle of the mountains.

Whatever be the planter's circumſtances in point of fortune, and our author thinks that he ought not to undertake a ſettlement without the command of 3000 or 4000 pounds ſterling, he ought not to ſet out with a great number of negroes. If he cannot command a plentiful ſupply of victuals from ſome contiguous plantation, ſix, or at the moſt twelve, male negroes, with one or two women, will be found ſufficient to make the firſt eſſay. After building two huts, one for the maſter or overſeer and the other for the ſlaves, they are to commence their operations by cutting away the underwood and creeping plants with the bill, and felling the trees. The trees are to be cut as low as poſſible, but the roots are to be left in the ground, becauſe they preſerve the ſoil during the firſt period of culture; and in burning this maſs of wood and ſhrubs, the only way ſometimes of clearing the ground, care muſt be taken that the fire be nowhere ſo violent as to convert the ſoil into the conſiſtence of brick, which it is very apt to do if the ſoil be clayey. Amid the coffee-trees, after they are planted may be ſown beans, maize, and all kinds of eſculent plants, pot herbs, and roots; but particular care muſt be taken to remove from theſe plantations all creeping plants, ſuch as melons, yams, potatoes, gourds, and more eſpecially tobacco, which multiplies to a vaſt extent, and exhauſts the ground.

In St Domingo the moſt approved method of planting the coffee-tree is in ſtraight rows croſſing each other at right angles, and the diſtance between the plants is regulated by the quality and expoſure of the ground. The richer the ſoil, the expoſures being the ſame, and the cooler the expoſure, the quality of the ſoil being the ſame, the farther muſt the trees be planted aſunder. If on the north and weſt the ground be good, plant ſtill farther; but, on the contrary, if to the eaſt or ſouth it be light (which it generally is), plant ſtill nearer. Thus if it be proper on a ſouth or eaſt expoſure to plant at the diſtance of ſix feet, it will be neceſſary to plant at the diſtance of ſeven on a weſt or north expoſure, if the ground be of the ſame quality as in the other ſituations.

Though coffee, like all other vegetables, grows from the ſeed, Dr Laborie adviſes, in the forming of large plantations, to make uſe of ſaplings reared in nurſeries; and the ſituation fitteſt for a nurſery is a plain, or at leaſt a ground of gentle aſcent, where the mould is crumbly. In forming a nurſery, ſome plant the whole berry; but our author recommends the taking off the ſkin, and waſhing the ſeparated ſeeds; in which we ſuſpect that he is miſtaken, as his practice is certainly a deviation from nature. The nurſery muſt be kept very clear of weeds, and neither corn nor any thing elſe ſown in it.

The beſt ſeaſon for tranſplanting the ſaplings is during the genial rains of April and May, when great attention is required, as the treaſures of future harveſts are at ſtake. Thoſe plants are the fitteſt for being removed which, in the language of our author, are *crowned*, or have each four little boughs; and, if the ſeeds were freſh and ſown in furrows about an inch from each other, this perfection is generally attained in the courſe of a year. The ſaplings muſt not be pulled up by force, but carefully raiſed by means of a flat, ſharp, iron ſhovel, thruſt deep under their roots; and the ſooner they are planted, after being taken up, the better.

In planting, the firſt thing to be done is to thruſt into the ground a dibble, or ſharp pointed ſtick, round which a hole is dug from nine to twelve inches in diameter, and from fifteen to eighteen in depth. Then a quantity of the mould taken out of the hole is thrown back into it, till its depth be diminiſhed about four or ſix inches; and the plant being ſupported with the left hand, in the middle of the hole, while the end of its ſtraight root, which our author calls its pivot, touches lightly the new bed, the ſurrounding mould is with the right hand thrown in, to the height of ſix inches. This being lightly preſſed down with both hands, more earth is thrown in and preſſed in the ſame manner, care being taken not to hurt, or bend, or diſplace the ſapling, which muſt be ſet ſo deep that its two inferior branches be rather below the level of the ground. On this account three or four inches of the hole are left open, which, by the time that theſe branches riſe above its margin, are filled up by the ſurrounding earth. The buſineſs is finiſhed by ſinking the ſharp-pointed ſtick at the upper margin of the hole, where it ſerves as a ſmall fence to the infant tree. In hot ſituations plantain trees are intermingled with the coffee-trees for the purpoſe of ſhade and coolneſs. They are uſually placed in every fourth or ſixth row, as the trees are more or leſs diſtant, and the expoſure more or leſs hot.

To the buſineſs of planting very ſoon ſucceeds that of weeding; for there is hardly any plant to which weeds are ſo pernicious as the coffee-tree: they cauſe it to grow yellow, fade, wither, and periſh. Where the ground ſlopes much, eſpecially if the ſoil be ſoft and friable, the weeds muſt be taken up by the hand; for if they be rooted out by the hoe, the ſoil will be ſo looſened that the rains will ſweep it away. Some weeds, however, from the depth of their roots muſt be dug up; and when that is the caſe the earth muſt be carefully returned and preſſed down. If, in weeding, any ſaplings be found withered, others of the ſame ſize muſt be brought from the nurſery and planted in their ſtead, with what our author calls their clod, *i. e.* with the earth of the nurſery adhering to their roots. If any ſapling be found broken or twiſted, it muſt be cut cloſe by the ground in a ſloping direction, the cut ſurface facing the north, and it will ſoon put forth ſuckers, of which the beſt only need be preſerved. In plantations of eighteen or twenty months old trees are often found with yellow, withered leaves, of which the cauſe is ſometimes a premature load of fruit, which muſt therefore be inſtantly removed or the tree will periſh. If, after this, it begin not in a few days to recover, it is probably eaten at the roots by a large white worm reſembling a ſlug. In that caſe the tree muſt be removed, the worm taken out, and before another tree be planted in its ſtead, a large hole muſt be made in the ground, expoſed to the influence of the ſun at leaſt for a fortnight.

The natural height of the coffee tree is from 15 to 18 feet; and if left to itſelf it would have the form of moſt other trees, *i. e.* a naked trunk and a branchy head. This is prevented by what the planters call *ſtopping;* which is performed by cutting off the top of the tree when it has arrived at the proper height, which varies according to circumſtances. In the beſt ſoil and moſt genial expoſure, it is ſuffered to grow to the height of five feet, and in the worſt ſtopped at two; but under the ſame aſpect, and on ground of the ſame quality, all the trees ought to be ſtopped at the ſame height. This operation of ſtopping is very apt to make the trees put forth ſuperfluous branches, which renders them inacceſſible to the genial warmth of the ſun, and, of courſe, deficient in the powers of fructification. Theſe muſt be *plucked* away while yet tender; for if they be ſuffered to grow till it become neceſſary to cut them, a number of ſprouts ſucceed; whereas, when they are plucked, the wound ſoon cicatrizes, and nothing follows.

The ſaw and the knife, however, muſt ſometimes be uſed; for when trees grow old their heads are apt to ſpoil; ſuperfluous branches may have been left upon them through neglect; a bough may have been broken by accident; or branches may be ſpent by too great a load of fruit. In all theſe caſes recourſe muſt be had to pruning, which ſhould be performed immediately after crop, and in ſuch a manner as that the tree, when it puts forth its new branches, may ſtill have as much as poſſible its natural or former appearance. This will be accompliſhed by cutting the withered bough immediately above a knot, whence a good ſecondary branch is put forth, which may be eaſily trained into the proper ſhape. Our author directs the cut to be always made ſo as that the ſloping ſurface ſhall face the north; by which expoſure it will eſcape the injury which it would otherwiſe receive from the exceſſive heat of the ſun. This is a good advice; but it would ſtill be an improvement on it to treat the wound with Forſyth's or Hit's plaſter, which we have deſcribed elſewhere (See *Encycl.* Vol. XVIII. page 562). When the tree is completely pruned, the moſs and other excreſcences muſt be ſcraped from the trunk with a wooden knife, great care being taken not to injure the bark.

After pruning follows what is called *nipping*. This is nothing more than the removal of thoſe ſuperfluous ſmall twigs which are ſent forth from every cut ſurface in ſuch numbers as would ſoon exhauſt the tree; and it is called nipping, becauſe they are plucked away by the hand, and not cut by the knife. It is needleſs to add, that when the ground begins to be impoveriſhed, it muſt be enriched by proper manure. This is known to every huſbandman both in Europe and in the Weſt Indies; but it is not perhaps ſo generally known that the weedings, and chiefly the red ſkins of coffee, when gathered into pits, are, in proceſs of time, converted into a black mould, which our author ſays makes the very beſt manure.

“ The fruit of the coffee, when perfectly ripe, appears like a ſmall oval cherry. Under a red and ſhining ſkin a whitiſh clammy luſcious pulp preſents itſelf, which generally incloſes two ſeeds. Theſe ſeeds have one ſide flat, the other hemiſpherical. The firſt is marked with a longitudinal fiſſure, and the flat ſides are applied to each other. When the ſeeds are opened, they are found covered with a white, ligneous, brittle membrane, denominated *parchment;* on the inſide of which is another ſilver-coloured membrane, exceedingly thin, and ſeeming to originate from the fiſſure of the ſeeds. Sometimes the cherry has but one ſeed or grain, which then is in the form of a ſmall egg. This is peculiar to old decayed trees, or to the extremities of ſome ſmall branches.”

The buſineſs of preparation conſiſts in taking the ſeed from its covering, in drying, and in cleaning it ſo as to have every advantage at market. Our author thinks that the beſt method of preparing the coffee is to ſtrip the ſeed of its outer ſkin immediately on its being pulled, and to dry it in its parchment. The proceſs has been already deſcribed in the Encyclopædia; but we believe it to be an injudicious one. We have the authority of a very eminent botaniſt*, well acquainted with all the vegetable productions of the Weſt Indies, to ſay, that the improvement which we have there mentioned, as propoſed by Mr Miller, is greatly preferable to Dr Laborie's practice. Indeed he himſelf admits, that coffee dried in the berry is more heavy than when dried in parchment, and that it generally has a higher flavour. Nay, he ſays expreſsly, that "if a planter wants to have coffee of the firſt quality, either for himſelf or for his friends, he muſt ſet apart a number of his oldeſt trees, and not gather the fruit till it is ripened into *dryneſs*. It is in that manner, he believes, that the Arabians in Yemen make their little harveſts; and he declares, that coffee thus nouriſhed on the tree to the laſt moment, muſt have every perfection of which it is capable." His only plauſible objection is, that the trees are ſoon exhauſted when the fruit is left ſo long upon them; but doubtleſs this exhauſtion might be retarded by proper manure.

* Wright.

The chemical analyſis of coffee evinces that it poſſeſſes a great portion of mildly bitter and lightly aſtringent gummous and reſinous extract; a conſiderable quantity of oil; a fixed ſalt; and a volatile ſalt.—Theſe are its medicinal conſtituent principles. The intention of torrefaction is not only to make it deliver thoſe principles, and make them ſoluble in water, but to give it a property it does not poſſeſs in the natural ſtate of the berry. By the action of fire, its leguminous taſte and the aqueous part of its mucilage are deſtroyed; its ſaline properties are created and diſengaged, and its oil is rendered empyreumatic.—From thence ariſes the pungent ſmell, and exhilarating flavour, not found in its natural ſtate.

The roaſting of the berry to a proper degree requires great nicety: Du Four juſtly remarks, that the virtue and agreeableneſs of the drink depend on it, and that both are often injured in the ordinary method. Bernier ſays, when he was at Cairo, where it is ſo much uſed, he was aſſured by the beſt judges, that there were only two people in that great city, in the public way, who underſtood the preparing it in perfection. If it be under-done, its virtues will not be imparted, and in uſe it will load and oppreſs the ſtomach:—If it be overdone, it will yield a flat, burnt, and bitter taſte, its virtues will be deſtroyed, and in uſe it will heat the body, and act as an aſtringent.

Fourteen pounds weight of raw coffee is generally reduced, at the public roaſting houſes in London, to eleven pounds by the roaſting; for which the dealer pays ſeven pence half-penny, at the rate of five ſhillings for every hundred weight. In Paris, the ſame quantity is reduced to ten pounds and an half. But the roaſting ought to be regulated by the age and quality of the coffee, and by nicer rules than the appearance of the fumes, and ſuch as are uſually practiſed: therefore the reduction muſt conſequently vary, and no exact ſtandard can be aſcertained. Beſides, by mixing different ſorts of coffee together, that require different degrees of heat and roaſting, coffee has ſeldom all the advantages it is capable of receiving to make it delicate, grateful, and pleaſant. This indeed can be effected no way ſo well as by people who have it roaſted in their own houſes, to their own taſte, and freſh as they want it for uſe. The cloſer it is confined at the time of roaſting, and till uſed, the better will its volatile pungency, flavour, and virtues, be preſerved.

The mode of preparing this beverage for common uſe differs in different countries, principally as to the additions made to it.—But though that is generally underſtood, and that taſte, conſtitution, the quality of the coffee, and the quantity intended to be drunk, muſt be conſulted, in regard to the proportion of coffee to the water in making it—yet there is one material point, the importance of which is not well underſtood, and which admits of no deviation.

The preſervation of the virtues of coffee, particularly when it is of a fine quality, and exempt from rankneſs, as has been ſaid, depends on carefully confining it after it has been roaſted; and not powdering it until the time of uſing it, that the volatile and æthereal principles, generated by the fire, may not eſcape. But all this will ſignify nothing, and the beſt materials will be uſeleſs, unleſs the following important admonition is ſtrictly attended to; which is, that after the liquor is made,—it ſhould be bright and clear, and entirely exempt from the leaſt cloudineſs or foul appearance, from a ſuſpenſion of any of the particles of the ſubſtance of the coffee.

There is ſcarcely any vegetable infuſion or decoction whoſe effects differ from its groſs origin more than that of which we are ſpeaking. Coffee taken in ſubſtance cauſes oppreſſion at the ſtomach, heat, nauſea, and indigeſtion: conſequently a continued uſe of a preparation of it, in which any quantity of its ſubſtance is contained, beſides being diſguſting to the palate, muſt tend to produce the ſame indiſpoſitions. The reſiduum of the roaſted berry, after its virtues are extracted from it, is little more than an earthy calx, and muſt therefore be injurious.

The want of attention to this circumſtance has been the cauſe of many of the complaints againſt coffee, and of the averſion which ſome people have to it; and it is from this conſideration that coffee ſhould not be prepared with milk inſtead of water, nor ſhould the milk be added to it on the fire, as is ſometimes the caſe, for economical dietetic purpoſes, where only a ſmall quantity of coffee is uſed, as the tenacity of the milk impedes the precipitation of the grounds, which is neceſſary for the purity of the liquor, and therefore neither the milk not the ſugar ſhould be added until after it is made with water in the uſual way, and the clarification of it is completed (A).—The milk ſhould be hot

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(A) It is not to coffee alone that this reflection is confined; every article we uſe as a diluter demands the ſame attention. Malt liquors, particularly ſmall beer, which in this reſpect is much neglected, ought always to be carefully fined. The fæculent matter entangled by the mucilage of the malt is hurtful to digeſtion, and detrimental to health.

when added to the liquor of the coffee, which ſhould alſo be hot, or both ſhould be heated together, in this mode of uſing coffee as an article of ſuſtenance.

If a knowledge of the principles of coffee, founded on examination and various experiments, added to obſervations made on the extenſive and indiſcriminate uſe of it, cannot authoriſe us to attribute to it any particular quality unfriendly to the human frame;—if the unerring teſt of experience has confirmed its utility, in many countries, not excluſively productive of thoſe inconveniences, habits, and diſeaſes, for which its peculiar properties ſeem moſt applicable—let thoſe properties be duly conſidered; and let us reflect on the ſtate of our atmoſphere, the food and modes of life of the inhabitants,—and the chronical infirmities which derive their origin from theſe ſources, and it will be evident what ſalutary effects might be expected from the general dietetic uſe of coffee in Great Britain.

COFFER Dams, or *Batardeaux*, in bridge-building, are incloſures formed for laying the foundation of piers, and for other works in water, to exclude the ſurrounding water, and ſo prevent it from interrupting the workmen.

COHANZY, or *Cæſaria*, a ſmall river, which riſes in Salem co. New-Jerſey, and running through Cumberland co. empties into Delaware river oppoſite the upper end of Bombay Hook. It is about 30 miles in length, and is navigable for veſſels of 100 tons to Bridgetown, 20 miles from its mouth.—*Morse.*

COHASSET, a townſhip in Norfolk co Maſſachuſetts, which was incorporated in 1770, and contains 817 inhabitants. It has a congregational church, and 126 houſes, ſcattered on different farms. Cohaſſet rocks, which have been ſo fatal to many veſſels, lie off this town, about a league from the ſhore. It lies 25 miles S. E. of Boſton; but in a ſtraight line not above half the diſtance.—*ib.*

COHGNAWAGA, a pariſh in the townſhip of Johnſtown, Montgomery co. New-York, on the W. ſide of Mohawk river, 26 miles W. of Schenectady. This place which had been ſettled nearly 80 years, and which was the ſeat of Sir William Johnſon, was moſtly deſtroyed by the Britiſh and Indians, under the command of Sir William, in the year 1780. In this action, Johnſon evinced a want of feeling which would have diſgraced a ſavage. The people deſtroyed in this expedition, were his old neighbours, with whom he had formerly lived in the habits of friendſhip. His eſtate was among them, and the inhabitants had always conſidered him as their friend and neighbour. Theſe unfortunate people, after ſeeing their houſes and property conſumed to aſhes, were hurried, ſuch as could walk, into cruel captivity; thoſe who could not walk, fell victims to the tomahawk and ſcalping knife.—*ib.*

COHOEZ, or the *Falls* in Mohawk river between 2 and 3 miles from its mouth, and 10 miles northward of Albany, are a very great natural curioſity. The river above the falls, is about 300 yards wide, and approaches them from the N. W. in a rapid current, between high banks on each ſide, and pours the whole body of its water over a perpendicular rock of about 40 (ſome ſay more) feet in height, which extends quite acroſs the river, like a mill dam. The banks of the river, immediately below the falls, are about 100 feet high. A bridge 1100 feet long, and 24 feet wide, reſting on 13 piers, was erected, at the expenſe of 12,000 dollars, in 1794, a mile below the falls, from which a ſpectator may have a grand view of them: but they appear moſt romantically from Lanſinburg hill, 5 miles E. of them.—*ib.*

COHONGORONTO, is the name of Potowmac river before it breaks through the Blue Ridge, in N. lat. 39. 45. Its whole length to the Blue Ridge, may be about 160 miles; from thence it aſſumes the name of *Potowmack.*—*ib.*

COHUIXCAS, a country in New-Spain, in which there is a conſiderable mountain of loadſtone, between Tcoiltylan and Chilapan.—*ib.*

COKESBURY COLLEGE, in the town of Abington, in Harford co. Maryland, is an inſtitution which bids fair to promote the improvement of ſcience, and the cultivation of virtue. It was founded by the Methodiſts, in 1785, and has its name in honor of Thomas Coke, and Francis Aſbury, the American biſhops of the Methodiſt Epiſcopal church. The edifice is of brick, handſomely built, on a healthy ſpot, enjoying a fine air, and a very extenſive proſpect. The college was erected, and is wholly ſupported by ſubſcription and voluntary donations. The ſtudents, who are to conſiſt of the ſons of travelling preachers, annual ſubſcribers, members of the ſociety, and orphans, are inſtructed in Engliſh, Latin, Greek, logic, rhetoric, hiſtory, geography, natural philoſophy, and aſtronomy; and when the finances of the college will admit, they are to be taught the Hebrew, French and German languages. The rules for the private conduct of the ſtudents extend to their amuſements; and all tend to promote regularity, encourage induſtry, and to nip the buds of idleneſs and vice. Their recreations without doors are, walking, gardening, riding, and bathing; within doors they have tools and accommodations for the carpenter's, joiner's, cabinet maker's, or turner's buſineſs. Theſe they are taught to conſider as pleaſing and healthful recreations, both for the body and mind.—*ib.*

COLAN, a ſmall Indian town, ſituated near the South Sea, 2 or 3 leagues to the northward of Payta, inhabited by fiſhermen. Here they make large rafts of logs, which will carry 60 or 70 tons of goods; with theſe they make long voyages, even to Panama, 5 or 600 leagues diſtant. They have a maſt with a ſail faſtened to it. They always go before the wind, being unable to ply againſt it; and therefore only fit for theſe ſeas, where the wind is always in a manner the ſame, not varying above a point or two all the way from Lima, till they come into the bay of Panama; and there they muſt ſometimes wait for a change. Their cargo is uſually wine, oil, ſugar, Quito cloth, ſoap, and dreſſed goat ſkins. The float is uſually navigated by 3 or 4 men, who ſell their float where they diſpoſe of their cargo; and return as paſſengers to the port they came from. The Indians go out at night by the help of the land-wind, with fiſhing floats, more manageable than the others, though theſe have maſts and ſails too, and return again in the day-time with the ſea wind.—*ib.*

COLCHESTER, the chief town in Eſſex, is deſcribed in the Encyclopædia; but the deſcription is in many reſpects erroneous. The following account of it as ſoon as they were expoſed to the air they mouldered to duſt. This adds another to the many facts, which prove that a race of enormous animals, now extinct, once inhabited the United States.—*ib.*

COLERAIN, a townſhip in Lancaſter co. Pennſylvania.—*ib.*

Colerain, a town on the N. bank of St Mary's river, Camden co. Georgia, 40 or 50 miles from its mouth. On the 29th of June, 1796, a treaty of peace and friendſhip was made and concluded at this place, between the Preſident of the United States, on the one part, in behalf of the United States, and the kings chiefs and warriors of the Creek nation of Indians, on the other. By this treaty, the line between the white people and the Indians, was eſtabliſhed to run "from the Currahee mountain to the head or ſource of the main ſouth branch of the Oconee river, called, by the white people, Appalatohee, and by the Indians, Tulapoeka, and down the middle of the ſame." Liberty was alſo given by the Indians to the Preſident of the United States, to "eſtabliſh a trading or military poſt on the S. ſide of Alatamaha, about 1 mile above Beard's bluff, or any where from thence down the river, on the lands of the Indians;" and the Indians agreed to "annex to ſaid poſt a tract of land of five miles ſquare; and in return for this, and other tokens of friendſhip on the part of the Indians, the United States ſtipulated to give them goods to the value of 6000 dollars, and to furniſh them with two blackſmiths with tools.—*ib.*

COLRAINE, a townſhip in Hampſhire co. Maſſachuſetts, which contains 229 houſes, and 1417 inhabitants.—*ib.*

COLIMA, a large and rich town of Mechoacan and New-Spain, on the S. Sea, near the borders of Xaliſca, and in the moſt pleaſant and fruitful valley in all Mexico, producing cocoa, caſſia, and other things of value, beſides ſome gold. Dampier takes notice of a volcano near it, with two ſharp peaks, from which ſmoke and flame iſſue continually. The famous plant oleacazan grows in the neighbourhood, which is reckoned a catholicon for reſtoring decayed ſtrength, and a ſpecific againſt all ſorts of poiſon. The natives apply the leaves to the parts affected, and judge of the ſucceſs of the operation by their ſticking or falling off.—*ib.*

COLOURS. See Pigments in this Supplement.

Accidental Colours, a name given to a very curious optical phenomenon, which was firſt, we believe, attended to by Buffon. That philoſopher wrote a ſhort paper on it, which was publiſhed in the Memoirs of the Academy of Sciences for the year 1743.

If a perſon look ſtedfaſtly and for a conſiderable time at a ſmall *red* ſquare painted upon *white* paper, he will at laſt obſerve a kind of green-coloured border ſurround the red ſquare. If he now turn his eyes to ſome other part of the paper, he will ſee an imaginary ſquare of a delicate green bordering on blue, and correſponding exactly in point of ſize with the red ſquare. This imaginary ſquare continues viſible for ſome time, and indeed does not diſappear till the eye has viewed ſucceſſively a number of new objects. It is to this imaginary ſquare that the improper name of *accidental colour* has been given. If the ſmall ſquare be *yellow*, the imaginary ſquare or accidental colour is blue: the accidental colour of green is red; of blue, yellow; of white, black; and on the contrary, that of black is white.

The firſt perſon, as far as we know, who gave a ſatisfactory explanation of theſe phenomena was Profeſſor Scherffer of Vienna, whoſe diſſertation, tranſlated by Mr Bernouilli, has been pubiſhed in the 26th volume of the Journal de Phyſique.

In order to underſtand theſe phenomena, let us recollect, in the firſt place, that light conſiſts of ſeven rays, namely, red, orange, yellow, green, blue, indigo, violet; that whiteneſs conſiſts in a mixture of all theſe rays; and that thoſe bodies which reflect but very little light are black. Thoſe bodies that are of any particular colour, reflect a much greater quantity of the rays which conſtitute that particular colour than of any other rays. Thus red bodies reflect moſt red rays; green bodies, moſt green rays, and ſo on.

Let us recollect, in the ſecond place, that when two impreſſions are made at the ſame time upon any of our organs of ſenſation, one of which is ſtrong and the other weak, we only perceive the former. Thus if we examine by the priſm the rays reflected by a red roſe, we ſhall find that they are of four kinds, namely, red, yellow, green, and blue. In this caſe, the impreſſion made by the red rays makes that made by the others quite inſenſible. For the ſame reaſon, when a perſon goes from broad day light into an ill-lighted room, it appears to him at firſt perfectly dark, the preceding ſtrong impreſſion rendering him for ſome time incapable of feeling the weaker impreſſion.

With the aſſiſtance of theſe two remarks, it will not be difficult to explain the phenomena of accidental colours. When a perſon conſiders attentively for ſome time a white ſquare lying on any black ſubſtance (paper for inſtance), it is evident that the part of the retina on which the white ſquare is painted, receives a ſtronger impreſſion than any other part; at leaſt the greateſt number of rays ſtrike upon it. A weaker impreſſion, therefore, will act on it with much leſs force than upon the reſt of the retina. Conſequently, when the eye is turned from the white ſquare to ſome other part of the black paper, a ſquare is perceived of the ſame ſize with the white ſquare, and much blacker than any other part of the paper; this is evidently in conſequence of the weaker impreſſion made by the rays reflected by the black paper upon that part of the eye previouſly fatigued by the copious reflection from the white ſquare. For the very ſame reaſon, if, after looking for a ſufficient time at a white ſquare lying on a black ground, we turn our eyes upon a ſheet of white paper, we perceive a very well defined black ſquare. In this caſe, the part of the retina already fatigued is not ſo ſenſible to the rays reflected by the white paper as the other parts of it which have not been fatigued. The reaſon then that *black* is the accidental colour of white is ſufficiently evident.

On the contrary, when we look a ſufficient time at a black ſquare lying upon a white ground, if we turn our eyes to any other part of the white paper, or even upon black paper, we ſhall perceive a ſmall ſquare anſwering to the black ſquare, and much brighter than any other part of the paper: evidently becauſe that part of the retina on which the black ſquare was painted being leſs fatigued, is more ſuſceptible of impreſſions than any other part of the eye. Thus we ſee why the accidental colour of black is white, and why that of white on the contrary is black. Theſe facts, indeed, have been long known, and they have been generally explained in this manner.

When a perſon has looked for a ſufficient time at a red ſquare placed on a ſheet of white paper, and then turns his eyes to another part of the paper, that part of the retina on which the red was painted being fatigued, the red rays reflected from the white paper ceaſe to make any ſenſible impreſſion on it, and conſequently there will be ſeen upon the white paper a ſquare ſimilar to the red ſquare, and the colour of which is that which would reſult from the mixture of all the rays of light except the red. In general, therefore, the *accidental colour* is the colour which reſults from the mixture of all the rays of light, thoſe rays excepted which are the ſame with the primitive colour.

Now in order to diſcover theſe accidental colours, let us recollect the manner which Newton employed to determine the colour which reſults from the mixture of ſeveral others, the ſpecies and quantity of which are known. He did it by dividing the circumference of a circle, ſo that the arches are to one another in the proportion of a ſtring ſhortened by degrees, in order to ſound, one after another, the notes of an octave ; which is nearly the proportion that the different rays occupy when light is decompoſed by means of the priſm. Or ſuppoſe the circumference of the circle, as uſual, divided into 360 degrees, the different rays, according to Benvenut, ſhould occupy the following arches :

Red,	45°.
Orange,	27.
Yellow,	48.
Green,	60.
Blue,	60.
Indigo,	40.
Violet,	80.

Let us now compare the action of colours on one another with that of different weights ; and for that purpoſe let us ſuppoſe each colour concentrated in the centre of gravity of its arch. In order to find the colour reſulting from any mixture, we have only to find the common centre of gravity of the arches which repreſent the different colours : The colour reſulting from the mixture will be that of the arch to which the common centre of gravity approaches neareſt. And if that common centre of gravity is not in the ſtraight line which joins the centre of the circle, and the centre of gravity of the arch to which it is moſt contiguous, the reſulting colour will approach more or leſs to the colour of the contiguous arch, towards which the line, paſſing through the centre of the circle, and the common centre of gravity of the arches, falls. And farther, the reſulting colour will be more or leſs deep according to the diſtance of the common centre of gravity from the centre of the circle.

In the caſe under conſideration at preſent, namely, to determine the different accidental colours, the application of this method is remarkably eaſy ; becauſe only one of the ſeven primitive colours is excluded, and conſequently the ſix colours from the mixture of which we wiſh to know the reſulting colour are all contiguous. For it is evident, that the ſum of the ſix arches, repreſenting theſe ſix colours, will be divided into two equal parts by the line which paſſes through the centre of the circle and their common centre of gravity ; and that if the ſame line be produced till it reaches the circumference of the circle on the other ſide, it will alſo divide the arch repreſenting the ſeventh or omitted colour into two equal parts. Let us ſuppoſe, for inſtance, that the violet is omitted, and that we wanted to know the colour reſulting from the mixture of the other ſix colours, we have only to biſect the arch repreſenting the violet, and from the point of ſection to draw a diameter to the circle, the arch of the circle oppoſite to the violet through which the diameter paſſes will indicate the colour of the mixture. The arch repreſenting the violet being 80°, let us take the half of it which is 40°, and let us add to it 45° for the red, 27° for the orange, and 48° for the yellow, we ſhall have 160°, which wants 20° of half the circumference of the circle. If now we add the 60° for the green, the ſum total will be 220°, conſiderably more than half the circumference. Conſequently the common centre of gravity is neareſt the green arch ; but it falls 10° nearer the yellow than the ſtraight line which joins the centre of the circle and the centre of gravity of the green arch. Hence we ſee that the reſulting colour will be green, but that it will have a ſhade of yellow.

It is evident, then, that the accidental colour of violet muſt be green with a ſhade of yellow ; and this is actually the caſe, as any one may convince himſelf by making the experiment.

Suppoſe, now, we wanted to know the accidental colour of *green*, or which is the ſame thing, the colour reſulting from the mixture of all the primitive rays except the green. The green arch is 60°, the half of which is 30° ; if to this we add 60° for the blue arch, and 40° for the indigo arch, we ſhall have 130°, or 50° degrees leſs than a ſemicircle. If to this we add the violet arch, which is 80°, we ſhall have 30° more than the ſemicircle ; conſequently the common centre of gravity falls neareſt the violet, and it is 10° nearer the red arch than is the centre of gravity of the violet arch. Hence we know that the accidental colour of green will be violet or purple, with a ſhade of red : And experiment confirms this.

Buffon obſerved, that the accidental colour of blue was reddiſh and pale. Let us ſee whether we ſhall obtain the ſame reſult from our method. Let us ſuppoſe that Buffon employed a light blue. In that caſe, if to 30, the half of the blue arch, we add 60 for the green, 48 for the yellow, and 27 for the orange, we ſhall have 165°, or 15° leſs than half the circumference of the circle : Conſequently the common centre will fall neareſt the red arch, but within 15° of the orange. The accidental colour muſt therefore be red, with a ſhade of orange ; or, which is the ſame thing, it muſt be a pale red.

In the ſame manner we may diſcover, that the accital colour of indigo is yellow, inclining a good deal to orange, and that the accidental colour of indigo and blue together is orange, with a ſtrong ſhade of red. Both of which correſpond accurately with experiment.

It would be eaſy to indicate in the ſame manner, the accidental colour of any primitive colour, if what has been ſaid were not ſufficient to explain the cauſe of accidental colours, and to ſhow that their phenomena correſpond exactly, both with the Newtonian theory of optics, and with what we know to be laws of our ſenſations in other particulars.

From the theory above given, which is that of Profeſſor Scherffer, the following conſequences may be deduced :

1. The accidental colour of a red ſquare lying upon a white or black ground, ought to be blackiſh, if we caſt our eyes upon a red coloured ſurface. 2. If the ſurface upon which we look at a red ſquare be itſelf coloured, if it be yellow, for inſtance, the white paper upon which we afterwards caſt our eyes, will appear blue, with a green ſquare in it correſponding to the original red ſquare. And, in general, we ought to perceive the accidental colour of the ground on which the ſquare is placed as well as the ſquare itſelf. 3. If while we are looking at the little ſquare we change the ſituation of the eye, ſo that its image ſhall occupy a different place on the retina, when we turn our eyes to the white paper, we ſhall ſee two ſquares, or at leaſt one unlike the figure of the original one. 4. If the white paper on which we look be farther diſtant than the little ſquare was, the imaginary ſquare will appear conſiderably larger than the true one. 5. If while we are looking at the little ſquare we gradually make the eye approach to it without altering its ſituation, the imaginary ſquare will appear with a pale border. Theſe and many other conſequences that might eaſily be deduced, will be found to take place conſtantly and accurately, if any one chooſes to put them to the teſt of experiment; and therefore may be conſidered as a complete confirmation of the theory given above of the cauſe of accidental colours.

There is another circumſtance reſpecting accidental colours which deſerves attention. If we continue looking ſtedfaſtly at the little ſquare longer than is neceſſary, in order to perceive its accidental colour, we ſhall at laſt ſee its border tinged with the accidental colour of the ground on which the ſquare is lying. For inſtance, if a white ſquare be placed upon blue paper, its border becomes yellow; if upon red paper it becomes green; and it becomes reddiſh upon green. In like manner the border of a yellow ſquare becomes greeniſh upon a red ground, and that of a red ſquare on a green ground becomes purple.

The cauſe of this phenomenon ſeems to depend upon the contraction and extenſion of the image of the ſquare painted on the retina. We know for certain, that the diameter of the pupil changes during our inſpecting the ſquare; at firſt it becomes leſs, and afterwards increaſes. And though we cannot ſee what paſſes in the bottom of the eye, we can ſcarcely doubt that ſimilar movements are going on there, if we attend to the changes they are continually taking place in the border of our little ſquare; ſometimes it is large, ſometimes ſmall; at one time it diſappears altogether, and the next moment makes its appearance again.

There is another phenomenon connected with accidental colours, which is not ſo eaſy to explain, namely, that if we look at theſe little ſquares for a very long time, till the eye is very much fatigued, their accidental colours will appear even after we ſhut our eyes. The very ſame thing takes place if we attempt to look at a very luminous object, as the ſun, for inſtance. Profeſſor Scherffer thinks that this may be partly owing to the light which ſtill paſſes through the eye-lids. That ſome light paſſes through the eye-lids, is evident, becauſe when we look towards a ſtrong light with our eye-lids ſhut, we ſee diſtinctly their colour, derived from the blood-veſſels with which they are filled; and if we paſs our finger before our eyes, we ſee the ſhadow of the finger though our eye-lids be ſhut, provided our eyes be turned towards the window. But that this light is not ſufficient to explain the phenomenon in queſtion is evident from this circumſtance, that the ſame accidental colours make their appearance, though we go immediately into the darkeſt place. Perhaps we have accounted for the phenomenon elſewhere (See Metaphysics, *Encycl.* n° 54.). We paſs over the other conjectures of Profeſſor Scherffer, which are exceedingly ingenious, but not ſufficiently ſupported by facts to be admitted.

COLUMBA Noachi, *Noah's dove*, a ſmall conſtellation in the ſouthern hemiſphere, conſiſting of 10 ſtars.

COLUMBIA, a townſhip in Waſhington co. diſtrict of Maine, on Pleaſant river, adjoining Machias on the N. E. and was formerly called Plantations No. 12 and 13. It was incorporated in 1796. The town of Machias lies 15 miles to the eaſtward. It is 9 miles from Steuben.—*Morse.*

Columbia *County*, in New-York, is bounded N. by Renſſelaer, S. by Ducheſs, E. by the ſtate of Maſſachuſetts, and W. by Hudſon river, which divides it from Albany co. It is 32 miles in length and 21 in breadth, and is divided into eight towns; of which Hudſon, Claverack, and Kinderhook are the chief. It contained, in 1790, 27,732 inhabitants, and in 1796, 3560 electors.—*ib.*

Columbia, a poſt town, the capital of Kerſhaw co. and the ſeat of government of South-Carolina. It is ſituated in Camden diſtrict, on the E. ſide of the Congaree, juſt below the confluence of Saluda and Broad rivers. The ſtreets are regular, and the town contains upwards of 70 houſes. The public offices have, in ſome meaſure, been divided, for the accommodation of the inhabitants of the lower counties, and a branch of each retained in Charleſton. It lies 115 miles N. N. W. of Charleſton, 35 S. W. of Camden, 85 from Auguſta, in Georgia, and 678 S. W. of Philadelphia. N. lat. 34. 1. W. long. 80. 57.—*ib.*

Columbia, a flouriſhing poſt town in Goochland co. Virginia, on the N. ſide of James river, at the mouth of the Rivanna. It contains about 40 houſes, and a warehouſe for the inſpection of tobacco. It lies 45 miles above Richmond, 35 from Charlotteſville, and 328 S. W. of Philadelphia.—*ib.*

Columbia, a town newly laid out, in Lancaſter co. Pennſylvania, on the N. E. bank of Suſquehanna river, at Wright's ferry; 10 miles W. of Lancaſter, and 76 W. by N. of Philadelphia.—*ib.*

Columbia *Co.* in the Upper diſtrict of Georgia, is bounded by Savannah river on the N. E. and E. which ſeparates it from the ſtate of S. Carolina, N. W. of Richmond co. Its ſhape is very irregular.—*ib.*

Columbia, a town in the N. W. territory, on the N. bank of Ohio river, and on the W. ſide of the mouth of Little Miami river; about 6 miles S. E. by E. of Fort Waſhington, 8 E. by S. of Cincinnati, and 87 N. by W. of Lexington, in Kentucky. N. lat. 39. 20. —*ib.*

COMANA, a town and province in the northern diviſion of Terra Firma, S. America. It lies on the N. eaſternmoſt part of the ſea coaſt.—*ib.*

COMAR, or Khomar, a Zemindar's demeſne of land.

COMARGO, a town of New-Leon, in N. America, ca, ſituated on the S. ſide of Rio Bravo, which empties into the gulf of Mexico on the W. ſide.—*Morſe.*

COMBAHEE, a conſiderable river of South-Carolina, which enters St Helena ſound between Cooſa and Aſhepoo rivers.—*ib.*

COMBAHEE *Ferry*, on the above river, is 17 miles from Jackſonſborough, 15 from Pocotaligo and 52 from Charleſton.—*ib.*

COMBUSTION. See CHEMISTRY in this Supplement, n° 293.

COMFORT, POINT, is the S. eaſternmoſt part of Elizabeth city co. in Virginia, formed by James river at its mouth in Cheſapeak bay. Point Comfort lies 19 miles W. by N. of Cape Henry.—*Morſe.*

COMMANOES, one of the ſmall Virgin iſles, in the Weſt-Indies, ſituated to the N. N. E. of Tortula. N. lat. 18. 25. W. long. 63.—*ib.*

COMPASS, or MARINER'S STEERING COMPASS, is an inſtrument of ſo great value, that every improvement of it, propoſed by men of ſcience or of experience, is intitled to notice. We ſhall therefore lay before our readers ſome obſervations on the defects of the compaſs in common uſe which have fallen into our hands ſince the article in the Encyclopædia was publiſhed. The firſt is by Captain O'Brien Drury of the royal Navy, and relates entirely to the needle.

“ Experience (ſays this officer) ſhews us, that the needle of a compaſs, as well as all other magnets, whether artificial or real, perpetually loſes ſomething of its magnetic powers, which often produces a difference exceeding a point; and I am well convinced that the great errors in ſhip-reckonings proceed more frequently from the incorrectneſs of the compaſs than from any other cauſe.

“ Steele cannot be too highly tempered for the needle of a ſea compaſs, as the more it is hardened the more permanent is the magnetiſm it receives; but to preſerve the magnetiſm, and conſequently the polarity of the needle, I recommend to have the needle caſed with thin, well-poliſhed, ſoft iron; or elſe to have it armed at the poles with a bit of ſoft iron. I have found, from many experiments, that the caſed needle preſerved its magnetiſm in a much more perfect degree than the needle not caſed; and I have ſometimes thought that the magnetic power of the caſed needle had increaſed, while the magnetic power of the uncaſed and unarmed needle always loſes of its polarity.”

This is not an opinion taken up at random, but is the reſult of what appears to have been a fair and judicious experiment; for our author placed a caſed needle, an armed needle, and one without either caſe or armour, in a room for three months; each having at that time preciſely the ſame direction, and nearly the ſame degree of force. At the expiration of the three months, he found that the caſed needle and the armed needle had not in the leaſt changed their direction; but the other had changed two degrees, and had loſt very conſiderable of its magnetic power. If there was any change in either of the other needles, it was too inconſiderable to be perceived.

Theſe obſervations ſeem to be new, and may tend to the improvement of the compaſs. But it is not with reſpect to the needle only that this inſtrument is defective. Mr Bernard Romans of Penſacola well obſerves, that, on another account, the heavieſt braſs compaſſes now in uſe are by no means to be relied on in a hollow or high ſea. This is owing to the box hanging in two braſs rings, confining it to only two motions, both vertical and at right angles with each other; by which confinement of the box, upon any ſucceſſion, more eſpecially ſudden ones, the card is always put into too much agitation, and before it can well recover itſelf, another jerk prevents its pointing to the pole; nor is it an extraordinary thing to ſee the card unſhipped by the violence of the ſhip's pitching.

All theſe inconveniences are remedied to the full by giving the box a vertical motion at every degree and minute of the circle, and compounding theſe motions with a horizontal one of the box as well as of the card. By this unconfined diſpoſition of the box, the effects of the jerks on the card are avoided, and it will always very ſteadily point to the pole. “ Experience (ſays our author) has taught me, that the card not only is not in the ſmalleſt degree affected by the hollow ſea, but that, in all the violent ſhocks and whirlings the box can receive, the card lies as ſtill as if in a room unaffected by the leaſt motion.

“ Lately a compaſs was invented and made in Holland, which has all theſe motions. It is of the ſize of the common braſs compaſſes; the bottom of the braſs box, inſtead of being like a bowl, muſt be raiſed into a hollow cone like the bottom of a common glaſs bottle; the vertex of the cone muſt be raiſed ſo high as to leave but one inch between the card and the glaſs; the box muſt be of the ordinary depth, and a quantity of lead muſt be poured in the bottom of the box, round the baſe of the cone; this ſecures it on the ſtile whereon it traverſes.

“ This ſtile is firmly fixed in the centre of a ſquare wooden box, like the common compaſs, except that it requires a thicker bottom. The ſtile muſt be of braſs, about ſix inches long, round, and of the thickneſs of one-third of an inch; its head blunt, like the head of a ſewing-thimble, but of a good poliſh: the ſtile muſt ſtand perpendicular. The inner vertex of the cone muſt alſo be well poliſhed; the vertical part of the cone ought to be thick enough to allow of a well-poliſhed cavity, ſufficient to admit a ſhort ſtile, proceeding from the centre of the card whereon it traverſes. The compaſs I ſaw was ſo conſtructed; but I ſee no reaſon why the ſtile might not proceed from the centre of the vertex of the cone, and ſo be received by the card the common way. The needle muſt be a magnetic bar, blunt at each end; the glaſs and cover are put on in the common way.”

A compaſs of this kind was ſubmitted to our author's examination by the captain of a ſloop of war, who aſſured him, that in a hard gale, which laſted ſome days, there was no other compaſs of the ſmalleſt ſervice. Mr Romans was ſatisfied that the officer did not praiſe the apparatus more than it deſerved: and we feel ourſelves ſtrongly inclined to be of the ſame opinion.

It muſt not be concealed, however, that the ingenious Mr Nicholſon ſeems to think very differently of all ſuch contrivances. In a paper publiſhed in the ninth number of his valuable Journal, he labours to prove, that the compaſs is very little diſturbed by tilting the box on one ſide, but very much by ſudden horizontal changes of place; that a ſcientific proviſion againſt the latter is therefore the chief requiſite in a well made inſtrument of this kind; and that no other proviſion is requiſite, or can eaſily be obtained, than good workmanſhip according to the common conſtruction, and a proper adjuſtment of the weight with regard to the centres or axes of ſuſpenſion. The ſame author is of opinion, that it would greatly improve the compaſs to make the needle flat and thin, and to ſuſpend it, not, as is moſt commonly done, with its flat ſide, but with its edge uppermoſt; for it being a well-known fact, that ſoft ſteel loſes its magnetiſm ſooner than hard, it is obvious, that unleſs both ſides of a needle be equally hard (which is almoſt impoſſible if they be diſtant from each other), the magnetic power will, in proceſs of time, deviate towards the harder ſide.

The Chineſe Compass has ſome advantages over the European compaſs, from which it differs with reſpect to the length of the needle, and the manner in which it is ſuſpended. In the compaſs of China, the magnetic needle is ſeldom above an inch in length, and is leſs than a line in thickneſs. It is poiſed with great nicety, and is remarkably ſenſible, or, in other words, points ſteadily towards the ſame portion of the heavens. This ſteadineſs is accompliſhed by the following contrivance: "A piece of thin copper is ſtrapped round the centre of the needle. This copper is rivetted by its edges to the upper part of a ſmall hemiſpherical cup, of the ſame metal, turned downwards. The cup ſo inverted ſerves as a ſocket to receive a ſteel pivot riſing from a cavity made into a round piece of light wood or cork, which thus forms the compaſs-box. The ſurfaces of the ſocket and pivot, intended to meet each other, are perfectly poliſhed, to avoid, as much as poſſible, all friction. The cup has a proportionably broad margin, which, beſide adding to its weight, tends, from its horizontal poſition, to keep the centre of gravity, in all ſituations of the compaſs, nearly in coincidence with the centre of ſuſpenſion. The cavity, in which the needle is thus ſuſpended, is in form circular, and is little more than ſufficient to remove the needle, cup, and pivot. Over this cavity is placed a thin piece of tranſparent talc, which prevents the needle from being affected by any motion of the external air; but permits the apparent motion of the former to be eaſily obſerved. The ſmall and ſhort needle of the Chineſe has a material advantage over thoſe of the uſual ſize in Europe, with regard to the inclination or dip towards the horizon; which, in the latter, requires that one extremity of the needle ſhould be made ſo much heavier than the other as will counteract the magnetic attraction. This being different in different parts of the world, the needle can only be accurately true at the place for which it had been conſtructed. But in ſhort and light needles, ſuſpended after the Chineſe manner, the weight below the point of ſuſpenſion is more than ſufficient to overcome the magnetic power of the dip or inclination in all ſituations of the globe; and therefore ſuch needles will never deviate from their horizontal poſition.

COMPLEMENT, in general, is what is wanting, or neceſſary, to complete ſome certain quantity or thing.

Arithmetical Complement, is what a number or logarithm wants of unity or 1 with ſome number of cyphers. It is beſt found by beginning at the left-hand ſide, and ſubtracting every figure from 9, except the laſt, or right hand figure, which muſt be ſubtracted from 10. So, the arithmetical comp. of the log. 9·5329714,
by ſubtracting from 9's, &c. is 0·4670286.

The arithmetical complements are much uſed in operations by logarithms, to change ſubtractions into additions, which are more conveniently performed, eſpecially when there are more than one of them in the operation.

Complement, in aſtronomy, is uſed for the diſtance of a ſtar from the zenith; or the arc contained between the zenith and the place of a ſtar which is above the horizon. It is the ſame as the complement of the altitude, or co-altitude, or the zenith diſtance.

Complement of the Courſe, in navigation, is the quantity which the courſe wants of 90°, or 8 points, *viz.* a quarter of the compaſs.

Complement of the Curtain, in fortification, is that part of the anterior ſide of the curtain which makes the demigorge.

Complement of the Line of Defence, is the remainder of that line, after the angle of the flank is taken away.

Complements of a Parallelogram, or *in a Parallelogram*, are the two leſſer parallelograms, made by drawing two right lines parallel to each ſide of the given parallelogram, through the ſame point in the diagonal.

Complement of Life, a term much uſed, in the doctrine of life annuities, by De Moivre; and, according to him, it denotes the number of years which a given life wants of 86, this being the age which he conſidered as the utmoſt probable extent of life. So 56 is the complement of 30, and 30 is the complement of 56.

COMPOSITION *of proportion*, according to the 15th definition of the 5th book of Euclid's Elements, is when, of four proportionals, the ſum of the 1ſt and 2d is to the 2d, as the ſum of the 3d and 4th is to the 4th.

Composition of Ratios, is the adding of ratios together; which is performed by multiplying together their correſponding terms, viz. the antecedents together, and the conſequents together, for the antecedent and conſequent of the compound ratio; like as the addition of logarithms is the ſame thing as the multiplication of their correſponding numbers. Or, if the terms of the ratio be placed fraction-wiſe, then the addition or compoſition of the ratios is performed by multiplying the fractions together.

COMPOSTELLA, a very rich town in New-Spain, and province of Xaliſco, built in 1531, ſituated near the S. Sea, 400 miles N. W. of Mexico. The ſoil is barren and the air unhealthful; but it has ſeveral mines of ſilver at St Pecaque, in its neighborhood. N. lat. 21. 20. W. long. 109. 42.—*Morſe.*

COMPOUND Interest. See Algebra, *Encycl.* and *Compound* Interest in this *Supplement.*

CANAJOHARY, a poſt town, on the S. ſide of Mohawk river, New-York, very large, 36 miles above Schenectady, and 318 from Philadelphia.—*Morſe.*

CONAWANGO, a northern branch of Alleghany river, in Pennſylvania, which riſes from Chataughque lake.—*ib.*

CONCEPTION, a city of Chili in South America, was viſited in 1786 by the celebrated, though unfortunate, navigator La Perouſe, who gives an account of ſome particulars relating to it very different from what we have given of it under the article Conception, *Encycl.*

cycl. So far are the Spaniards from living in ſecurity with reſpect to the Indians, that, according to him, they are under continual alarms of being attacked by thoſe bold and enterpriſing ſavages. "The Indians of Chili (ſays he) are no longer thoſe Americans who were inſpired with terror by European arms. The increaſe of horſes, which are diſperſed through the interior of the immenſe deſerts of America, and that of oxen and ſheep, which has alſo been very great, have converted theſe people into a nation of Arabs, in every thing reſembling thoſe who inhabit the deſerts of Arabia. Conſtantly on horſeback, they conſider an excurſion of two hundred leagues as a very ſhort journey. They march accompanied by their flocks; feed upon their fleſh and milk, and ſometimes upon their blood; and cover themſelves with their ſkins, of which they make helmets, cuiraſſes, and bucklers. All their old cuſtoms are laid aſide. They no longer feed upon the ſame fruits, nor wear the ſame dreſs; but have a more ſtriking reſemblance to the Tartars, or to the inhabitants of the banks of the Red Sea, than to their anceſtors, who lived two centuries ago. So deciſive an influence has the introduction of two domeſtic animals had upon the manners of that once timid people. It is eaſy to conceive what formidable enemies they muſt now be to the Spaniards; for ſuppoſing them defeated in battle, How is it poſſible to follow them in ſuch long excurſions? How is it poſſible to prevent aſſemblages, which bring together in a ſingle point nations ſcattered over 400 leagues of country, and thus form armies of 30,000 men?"

Of theſe people M. Rollin, ſurgeon major of the frigate *la Buſſole*, gives the following phyſiological particulars: "They are, in general (ſays he), of lower ſtature, and leſs robuſt, than Frenchmen, though they endure with great courage the fatigues of war and all its attendant privations. There is a great ſameneſs in the phyſiognomy of moſt individuals. The face is larger and rounder than that of Europeans. The features are more ſtrongly marked. The eyes are ſmall, dull, black, and deeply ſeated. The forehead is low; the eyebrows black and ſhaggy; the noſe ſhort and flattened; the cheek-bones high; the lips thick; the mouth wide; and the chin diminutive. The women are ſhort, ill-made, and with diſguſting countenances. Both men and women bore their noſe and ears, which they adorn with glaſs or mother-of-pearl trinkets. The colour of their ſkin is a reddiſh brown: That of their nails is ſimilar, but not ſo deep. The hair of both is black, coarſe, and very thick. The men have little beard; but their arm-pits and parts of ſex are well furniſhed with hair, which parts, in moſt of the women, have none."

The military governor of Conception, who was an Iriſhman, returned, while M. de la Perouſe was there, from the frontiers of the Spaniſh ſettlements, where he had juſt concluded a glorious peace with the Indians. This peace was highly neceſſary to the people of his government, whoſe diſtant habitations were expoſed to the inroads of ſavage cavalry, whoſe practice it is to maſſacre the men and children, and to make the women priſoners. This amiable man, whoſe name was *Higguins* (probably *Higgins*), had ſucceeded in gaining the good will of theſe ſavages, and thereby rendered the moſt ſignal ſervice to the nation that had adopted him. For while the Indians and Spaniards are at variance, an alliance with the former by any of the maritime powers of Europe would become ſo formidable to the latter, as to induce them, for fear of their lives, to abandon their ſettlements in Chili, and retire to Peru. This was clearly ſeen by *Monneron* the engineer on the expedition, who, with the true ſpirit of a Frenchman, pointed out to his government the method of wreſting from its moſt faithful ally, one of the moſt valuable provinces in the Spaniſh empire.

La Perouſe deſcribes the common people of Conception as much addicted to thieving, and the women as exceedingly eaſy of acceſs. "They are a degenerated and mongrel race (ſays he); but the inhabitants of the firſt claſs, the true bred Spaniards, are polite and obliging in the extreme. The biſhop was a man of great ſenſe, of agreeable manners, and of a charity of which the Spaniſh prelates afford frequent examples." He was a Creole, and had never been in Europe. Of the monks, our author gives a very different character. "The misfortune (ſays he) of having nothing to do, the want of family ties, the profeſſion of celibacy, without being ſeparated from the world, and their living in the convenient retirement of their cells, has rendered, and could not fail to render, them the greateſt profligates in America. Their effrontery is inconceivable. I have ſeen ſome of them ſtay till midnight at a ball; aloof, indeed, from the good company, and ſeated among the ſervants. Theſe ſame monks gave our young men more exact information than they could get elſewhere, concerning places with which prieſts ought to have been acquainted only in order to interdict the entrance."

M. de la Perouſe repreſents that part of Chili, which is called *the Biſhoprick of Conception*, as one of the moſt fertile countries in the univerſe. Corn yields ſixty to one; the vineyards are equally productive; and the plains are covered with innumerable flocks, which, tho' left to themſelves, multiply beyond all imagination. Yet this colony is far from making the progreſs that might be expected from a ſituation ſo favorable to an increaſe of population. The influence of the government inceſſantly counteracts the climate and the ſoil. Prohibitory regulations exiſt from one end of Chili to the other; and this kingdom, of which the productions, if carried to the higheſt pitch, would feed the half of Europe; of which the wool would ſuffice for the manufactures of Great Britain and France, even when manufactures flouriſhed in the latter country; and of which the cattle, if ſalted down, would produce an immenſe revenue—is entirely deſtitute of commerce, and its inhabitants ſunk in ſloth and indolence. Unleſs, therefore, Spain change its ſyſtem entirely, Chili will never reach that pitch of proſperity which might be expected from its ſituation and fertility. For the latitude and longitude of Conception, ſee *Encycl.*

Conception, a large bay on the E. ſide of Newfoundland iſland, whoſe entrance is between Cape St Francis on the ſouthward, and Flamborough-head on the northward. It runs a great way into the land in a ſouthern direction, having numerous bays on the W. ſide, on which are two ſettlements, Carboniere and Havre de Grace. Settlements were made here in 1610, by about 40 planters, under governor John Guy, to whom king James had granted a patent of incorporation.—*Morse.*

wonderful things, the author inculcates the poſſibility, if not the probability, that the nature of man may be improved to abſolute perfection in body and mind, and his exiſtence in this world protracted to immortality. So firmly does he ſeem to have been perſuaded of the truth of this unphiloſophical opinion, that he ſet himſelf ſeriouſly to conſider how men ſhould conduct themſelves when the population ſhould become too great for the quantity of food which the earth can produce; and the only way which he could find for counteracting this evil was, to check population by promiſcuous concubinage and other practices, with an account of which we will not ſully our pages. Yet we are told by La Lande, that this ſketch is "only the outline of a great work, which, had the author lived to complete it, would have been conſidered as a monument erected to the *honour* of human nature!!!" La Lande, indeed, ſpeaks of the author in terms of high reſpect: and his abilities are certainly unqueſtionable: but what ſhall we think of the morals of that man, who firſt purſued with malicious reports, and afterwards hired ruffians to aſſaſſinate,* the old Duke of Rochefoucalt, in whoſe houſe he had been brought up; by whom he had been treated as a ſon; and at whoſe ſolicitation Turgot created for him a lucrative office; and by the power of the court raiſed him to all his eminence? There is a living Engliſh writer, who has laboured hard to prove that gratitude is a crime. Condorcet muſt ſurely have held the ſame opinion; and therefore could not blame thoſe low born tyrants who put him to death by what we would call *an unjuſt ſentence;* for it was in ſome degree to his writings that thoſe tyrants were indebted for their power.

Jour. de Phyſ. Nov. 1792.

About the end of the year 1786, Condorcet married Marie-Louiſe Sophie de Grouchy, whoſe youth, wit, and beauty, were leſs attractive in the eyes of a philoſopher than the tender and courageous anxiety with which ſhe watched the couch, and aſſuaged the ſufferings, of the ſon of the preſident du Paty, who had been bitten by a mad dog. This union, however, we are told, was fatal to his repoſe; it tempted him into the dangerous road of ambition; and the idea of providing for a wife and daughter induced him to ſeek for offices which once he would have deſpiſed.

CONDUSKEEG, a ſettlement in the diſtrict of Maine, in Hancock co. containing 567 inhabitants.—*Morse.*

CONEGOCHEAGUE *Creek*, riſes near Mercerſburg, Franklin co. Pennſylvania, runs ſoutherly in a winding courſe, and after ſupplying a number of mills, empties into the Potowmack, at William port, in Waſhington co. Maryland; 19 miles S. E. of Hancock, and 8 miles S. of the Pennſylvania line.—*ib.*

CONEMAUGH *River*, and Little Conemaugh, are the head waters of Kiſkemanitas, in Pennſylvania: after paſſing through Laurel hill and Cheſnut ridge, Conemaugh takes that name and empties into the Alleghany, 29 miles N. E. of Pittſburg. It is navigable for boats, and there is a portage of 18 miles between it and the Frankſtown branch of Juniata river.—*ib.*

CONENTES, LAS, a city of La Plata or Paraguay, in S. America, in the dioceſe of Buenos Ayres.

CONESTEO, a N. weſtern branch of Tioga river, in New-York.—*ib.*

CONESTOGA, a townſhip in Lancaſter co. Pennſylvania.—*ib.*

CONESUS, a ſmall lake in the Geneſſee country, N. York, which ſends its waters N. W. to Geneſſee river.—*ib.*

CONFERVA JUGALIS (ſee CONFERVA *Encycl.*) is introduced here merely on account of a curious circumſtance reſpecting it, which was communicated, not long ago, to the Philomatic Society at Paris. Citizens Charles and Romain Coquebert having collected ſome of this *Conferva* in the neighbourhood of Paris, aſcertained, by means of an excellent microſcope, conſtructed by Nairne and Blunt, that, in this ſpecies there are male and female filaments, which unite by an actual copulation; that certain globules contained in the male filaments paſs into the interior part of the female filaments; and that by this union there are formed in the latter ſeeds, or, if we may uſe the expreſſion, ſmall *ova*, which reproduce the ſpecies. This is the firſt inſtance, in the vegetable kingdom, of a reproduction abſolutely analogous to that which we find among animals. *Philoſophical Magazine*, n° 3.

May this fact be depended on? We queſtion not, in the ſlighteſt degree, the veracity of the editor of the very reſpectable miſcellany from which we have copied it; but we confeſs ourſelves inclined to admit the phyſiological diſcoveries of citizen philoſophers with great heſitation. The fact, if real, is certainly curious, and may lead to important concluſions; and we therefore recommend an inveſtigation of its truth to our botanical readers.

CONGAREE, a conſiderable river of S. Carolina, formed by the confluence of Saluda and Broad rivers. The union of the waters of Congaree and Wateree, from the Santee.—*Morse.*

CONGELATION, ſee CHEMISTRY in this Supplement, n° 284.

CONHOCTON *Creek*, in New-York, is the northern head water of Tioga river. Near its mouth is the ſettlement called Bath.—*Morse.*

CONNECTICUT, a ſtream in Long Iſland, N. York, which falls into a bay at the S. ſide of the iſland. It lies 2 miles to the ſouthward of Rockonkama pond.—*ib.*

CONTAGION (ſee *Encycl.*) is a ſubject on which much has been written to very little purpoſe. Of all the attempts which have been made to account for it, there is not one that can be thought ſatisfactory. This, however, is not perhaps a matter of great importance, if a method could only be diſcovered to ſtop the progreſs of contagion where it is known to have place. Among the many benefits which may be reaped from the late diſcoveries in Chemiſtry, even this deſideratum promiſes to be one; and we ſurely need not add one of the greateſt. Dr James Carmichael Smyth, phyſician extraordinary to his Majeſty, ſuggeſted, in the year 1795 or 1796, a proceſs for determining the effect of the nitric acid in deſtroying contagion; and experiments, according to his directions, were made on board the *Union* and other ſhips at Sheerneſs.

The Union was an hoſpital ſhip, and the experiment on board her was conducted by Mr Menzies, late ſurgeon to his Majeſty's ſloop Diſcovery, and by Mr Baſſan, ſurgeon of the Union; and when it is conſidered, Contagion.

Contag

that freſh contagion was daily pouring into the hoſpital from the Ruſſian veſſels, which were at that time lying in the Downs, and which had brought with them a ſpecies of fever that might in every ſenſe of the word be termed an epidemy, it will be allowed, that the ſucceſs which attended it was ſuch that it cannot be too generally known.

The wards were extremely crowded, and the ſick of every deſcription lay in cradles, promiſcuouſly arranged, to the number of nearly two hundred; of which, about one hundred and fifty were in different ſtages of the above malignant fever, which was extremely contagious, as appeared evident from its rapid progreſs and fatal effects among the attendants on the ſick and the ſhip's company.

The utenſils and materials provided for the proceſs were the following: A quantity of fine ſand, about two dozen quart earthen pipkins, as many common tea-cups, ſome long ſlips of glaſs to be uſed as ſpatulas, a quantity of concentrated vitriolic (ſulphuric) acid, and a quantity of pure nitre (nitrat of potaſh).

The proceſs was conducted in the following manner: 1*ſt*, All the ports and ſcuttles were ſhut up; the ſand, which had been previouſly heated in iron pots, was then ſcooped out into the pipkins by means of an iron ladle; and in this heated ſand, in each pipkin, a ſmall tea-cup was immerſed, containing about half an ounce of the ſulphuric acid, to which, after it had acquired a proper degree of heat, an equal quantity of nitrat of potaſh in powder was gradually added, and the mixture ſtirred with a glaſs ſpatula till the vapour aroſe from it in conſiderable quantity (A). The pipkins were then carried through the wards by the nurſes and convaleſcents, who kept walking about with them in their hands, occaſionally putting them under the cradles of the ſick, and in every corner where any foul air was ſuſpected to lodge. In this manner they continued fumigating, until the whole ſpace between decks was fore and aft filled with the vapour, which appeared like a thick haze.

The vapour at firſt excited a good deal of coughing among the patients, which gradually ceaſed as it became more generally diffuſed through the wards: part of this effect, however, was to be attributed to the inattention of thoſe who carried the pipkins, in putting them too near the faces of the ſick; which cauſed them to inhale the ſtrong vapour as it immediately iſſued from the cups.

The body-clothes and bed-clothes of the ſick were, as much as poſſible, expoſed to the nitrous vapour during the fumigation; and all the foul linen removed from them was immediately immerſed in a tub of cold water, afterwards carried on deck, rinſed out, and hung up till nearly dry, and then fumigated before it was taken to the waſh-houſe: a precaution extremely neceſſary in every caſe of infectious diſorder. Due attention was alſo paid to cleanlineſs and ventilation.

It took about three hours to fumigate the ſhip. In about an hour after, the vapour having entirely ſubſided, the ports and ſcuttles were thrown open for the admiſſion of freſh air. It could plainly be perceived that the air of the hoſpital was greatly ſweetened even by this firſt fumigation. The proceſs was repeated again next morning; and the people employed, being now better acquainted with it, were more expert, and finiſhed the whole in about an hour's time. In an hour afterwards, the vapour having entirely ſubſided, the freſh air was freely admitted into the hoſpital as before. Fewer pipkins were employed for the evening fumigations than for thoſe of the mornings, as the freſh air could not be admitted ſo freely after the former as the latter.

The pleaſing and immediate effect of the fumigation in deſtroying the offenſive and diſagreeable ſmell, ariſing from ſo many ſick crowded together, was now very perceptible, even to the nurſes and attendants; the conſequence of which was, that they began to place ſome degree of confidence in its efficacy, and approached the cradles of the infected with leſs dread of being attacked with the diſorder: ſo that the ſick were better attended, and the duty of the hoſpital was more regularly and more cheerfully performed. In ſhort, a pleaſing gleam of hope ſeemed now to caſt its cheering influence over that general deſpondency, which was before evidently pictured in every countenance, from the dread and horror each individual naturally entertained of being, perhaps, the next victim to the malignant powers of a virulent contagion.

It is a remarkable fact, that from the 26th of November 1795, when the fumigation was firſt reſorted to, till the 25th of December, not a perſon on board was attacked with the fever, though, in the three months preceding, more than one-third of all the people in the ſhip had been ſeized with the diſtemper, and of theſe more than one in four were carried off by it; and the probability is, that the ſickneſs and mortality would have gone on, increaſing in proportion to the diffuſion of the contagion, and to the increaſing deſpondency of the people, who conſidered themſelves as ſo many devoted victims.

The advantage of the fumigation was not felt by the ſhip's company and attendants alone, whom it preſerved from the baneful effects of the fever: the ſick and convaleſcents derived almoſt an equal benefit from it. The ſymptoms of the diſeaſe were meliorated, and loſt much of their malignant appearance; and the advantage of a pure air, and free from ſtench, to convaleſcents, may be readily conceived.

Great confidence is always dangerous. It proved ſo on the preſent occaſion. On the 17th of December they imagined themſelves ſo ſecure, that they diſcontinued the cuſtom of fumigating morning and evening, thinking that once a day was ſufficient. On the 25th, one of the nurſes ſuffered a ſlight attack; and on the 26th, a marine, who, for a week before, had been in a ſtate of intoxication, was ſeized with the fever, of which he died. Theſe two accidents gave immediate alarm: they returned again to the practice of fumigating twice a day; and from that time to the extermination of the diſorder,

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(A) That the fumes of the mineral acids poſſeſſed the property of ſtopping contagion was proved by Morveau as far back as the year 1773, who, by means of the fumes of muriatic acid extricated from the muriat of ſoda (ſea ſalt) by the ſulphuric acid, purified the air of the cathedral of Dijon, which had been ſo much infected by exhumations that they were obliged to abandon the building. See CHEMISTRY, n°. 428, in this *Supplement*.

We need hardly inform any of our readers, that a caſk has the appearance of two truncated cones joined at their baſes, or that the part where the junction appears to be made being the moſt capacious, or that of which the diameter is the largeſt, is vulgarly called the belly of the caſk. Theſe cones, however, were they completed, would not be regular, but rather *conoids*, being formed of pieces of timber, or ſtaves, which are not ſtraight lines as in the cone, but are curved from the vertex to the baſe.

In chuſing his wood, if he can have a choice, the cooper prefers old and thick and ſtraight trees, from which he hews thin planks to be formed into ſtaves; and in France, where this art is practiſed on a large ſcale, the winter months are allotted for the preparation of the ſtaves and bottoms, and the ſummer for putting them together or mounting the caſk. The author of the article in the *Encyclopedie Methodique* directs the cooper, when dreſſing the ſtaves with the plane, to cut the wood always acroſs; a practice which we doubt not is proper, though we think it would not be eaſy to aſſign the reaſon of it. Plaining is the moſt laborious and difficult part of the work; and there are but few coopers who plane quickly, and at the ſame time well. In ſhops where the work is diſtributed into parts, plaining is reckoned a great object; and in France, before the revolution, a good plainer gained from three ſhillings and threepence ſterling to four ſhillings and three farthings a day.

In forming the ſtaves, it muſt never be forgotten that each is to conſtitute part of a double conoid; that it muſt therefore be broadeſt at the middle, becoming gradually, though not in ſtraight lines, narrower towards the extremities; that the outſide acroſs the wood muſt be wrought into the ſegment of a circle; and that the ſtave muſt be thickeſt near the middle, growing thinner, by very gentle degrees, towards the ends. To adjuſt accurately theſe different curves (for even the *narrowing* of the ſtaves muſt be in a curve) to the ſize and intended ſhape of the caſk, would require either great experience, or a larger portion of mathematical ſcience than we have reaſon to think that many coopers poſſeſs. With reſpect to the inſide of the ſtave, it is of little conſequence whether it be rounded into the ſegment of a circle or not, and therefore the cooper very ſeldom takes that trouble.

The ſtaves being all dreſſed and ready to be arranged in a circular form, it might be thought neceſſary, in order to make the ſeems tight, to trim the thin edges, which are to be joined together, in ſuch a manner as that a ray paſſing from the outſide of the caſk through a ſeam to the centre, ſhould touch the contiguous ſtaves from the exterior to the interior ſide; in other words, that the thin edges ſhould be ſloped as the archſtones of a bridge are ſloped, ſo that the contiguous ſtaves may be brought into firm contact throughout the whole joint. This, however, is not the practice of the cooper. With great propriety he brings the contiguous ſtaves into contact at their inner ſurfaces only; ſo that by driving the hoops hard, he can make the joints much cloſer than he could poſſibly have done had the edges of the ſtaves been ſo ſloped as to permit them to touch each other throughout before being driven together by the compreſſion of the hoops. This, together with giving to the ſtaves the proper curvature, ſeems to be the only part of the cooper's work which deſerves the name of art; for the driving of the hoops and the forming of the bottoms could certainly be accompliſhed by any carpenter, we had almoſt ſaid by any man, though he had never ſeen a hoop driven or a bottom formed.

In many parts of Scotland, inſtead of ale or beer mugs, they uſe ſmall hooped wooden veſſels, of which the ſtaves are feather-edged or dove-tailed into one another. This, as the ſtaves are of different colours, increaſes the beauty of the veſſel, and to a ſuperficial obſerver appears to be an ingenious contrivance; but it adds nothing to the ſtrength or tightneſs of the ſeam, and cannot be attended with the ſmalleſt difficulty. We think, indeed, that in a large caſk or tub it would prove injurious to the ſeam; for either theſe dove-tails muſt be very thin ſlips raiſed from the interior edges of the ſtaves, which in many caſes could not be done if the wood were thoroughly ſeaſoned; or if they be cut out like inverted wedges, the contiguous ſtaves muſt be brought into contact from the interior to the exterior ſide previous to the driving of the hoops; and in that caſe, as we have ſeen, the ſeams could not be made completely tight.

COOPER, a large and navigable river which mingles its waters with Aſhley river below Charleſton city in S. Carolina. Theſe form a ſpacious and convenient harbor, which communicates with the ocean, juſt below Sullivan's iſland, which it leaves on the N. 7 miles S. E. of the city. In theſe rivers the tide riſes 6½ feet. Cooper river is a mile wide at the ferry, 9 miles above Charleſton.—*Morse.*

COOPER's *Iſland*, one of the leſſer Virgin Iſles in the Weſt-Indies, ſituated S. W. of Ginger Iſland, and uninhabited. It is 5 miles long, and 1 broad. N. lat. 18. 5. W. long. 62. 57.—*ib.*

COOPER's *Town*, a poſt town and townſhip, in Otſego co. New-York, and is the compact part of the townſhip of Otſego, and the chief town of the country round Lake Otſego. It is pleaſantly ſituated at the S. W. end of the lake, on its banks, and thoſe of its outlet; 12 miles N. W. of Cherry Valley, and 73 W. of Albany. Here are a court-houſe, gaol, and academy. In 1791, it contained 292 inhabitants. In 1789, it had but 3 houſes only; and in the ſpring 1795, 50 houſes had been erected, of which above a fourth part were reſpectable 2 ſtory dwelling-houſes, with every proportionable improvement, on a plan regularly laid out in ſquares. N. lat. 42. 44. W. long. 74. 48.—*ib.*

COOPER's *Town*, Pennſylvania, is ſituated on the Suſquehanna river. This place in 1785, was a wilderneſs. Nine years after, it contained 1800 inhabitants —a large and handſome church, with a ſteeple—a market houſe and a bettering houſe—a library of 1200 volumes, and an academy of 64 ſcholars. Four hundred and ſeventy pipes were laid under ground, for the purpoſe of bringing water from Weſt Mountain, and conducting it to every houſe in town.—*ib.*

COOP's *Town*, in Harford co. Maryland, lies 12 miles N. W. of Harford, and 22 N. eaſterly of Baltimore; meaſuring in a ſtraight line.—*ib.*

COOS, or *Cohos*, the country called *Upper* and *Lower Coos*, lies on Connecticut river between 20 and 40 miles above Dartmouth college. Upper Coos is the country

Copernicus. conjunction with the ſun, they are then in the ſide of their orbits which is almoſt oppoſite to, and moſt diſtant from, the earth, and therefore appears ſmalleſt and leaſt ſenſible to the eye. But as they then revolve in a direction which is almoſt contrary to that of the earth, they appear to advance forward with double velocity; as a ſhip that ſails in a contrary direction to another; appears from that other to ſail both with its own velocity and the velocity of that from which it is ſeen. On the contrary, when thoſe planets are in oppoſition to the ſun, they are on the ſame ſide of the ſun with the earth, are neareſt it, moſt ſenſible to the eye, and revolve in the ſame direction with it; but as their revolutions round the ſun are ſlower than that of the earth, they are neceſſarily left behind by it, and therefore ſeem to revolve backwards; as a ſhip which ſails ſlower than another, though it ſails in the ſame direction, appears from that other to ſail backwards. After the ſame manner, by the ſame annual revolution of the earth, he connected together the direct and retrograde motions of the two inferior planets, as well as the ſtationary appearances of all the five.

"Thus far did this new account of things render the appearances of the heavens more completely coherent than had been done by any of the former ſyſtems. It did this, too, by a more ſimple and intelligible, as well as more beautiful machinery. It repreſented the ſun, the great enlightener of the univerſe, whoſe body was alone larger than all the planets taken together, as eſtabliſhed immoveable in the centre, ſhedding light and heat on all the worlds that circulated around him in one uniform direction, but in longer or ſhorter periods, according to their different diſtances. It took away the diurnal revolution of the firmament, whoſe rapidity, upon the old hypotheſis, was beyond what even thought could conceive. It not only delivered the imagination from the embarraſſment of epicycles, but from the difficulty of conceiving theſe two oppoſite motions going on at the ſame time, which the ſyſtem of Ptolemy and Ariſtotle beſtowed upon all the planets; I mean, their diurnal weſtward, and periodical eaſtward revolutions. The earth's revolution round its own axis took away the neceſſity for ſuppoſing the firſt, and the ſecond was eaſily conceived when by itſelf. The five planets, which ſeem, upon all other ſyſtems, to be objects of a ſpecies by themſelves, unlike to every thing to which the imagination has been accuſtomed, when ſuppoſed to revolve along with the earth round the ſun, were naturally apprehended to be objects of the ſame kind with the earth, habitable, opaque, and enlightened only by the rays of the ſun. And thus this hypotheſis, by claſſing them in the ſame ſpecies of things, with an object that is of all others the moſt familiar to us, took off that wonder and uncertainty which the ſtrangeneſs and ſingularity of their appearance had excited; and thus far, too, better anſwered the great end of philoſophy.

"Neither did the beauty and ſimplicity of this ſyſtem alone recommend it to the imagination; the novelty and unexpectedneſs of that view of nature which it opened to the fancy, excited more wonder and ſurpriſe than the ſtrangeſt of thoſe appearances, which it had been invented to render natural and familiar, and theſe ſentiments ſtill more endeared it. For though it is the end of philoſophy to allay that wonder which either the unuſual or ſeemingly disjointed appearances of nature excite, yet ſhe never triumphs ſo much as when, in order to connect together a few, in themſelves perhaps inconſiderable objects, ſhe has, if I may ſay ſo, created another conſtitution of things, more natural indeed, and ſuch as the imagination can more eaſily attend to, but more new, more contrary to common opinion and expectation, than any of thoſe appearances themſelves. As in the inſtance before us, in order to connect together ſome ſeeming irregularities in the motions of the planets, the moſt inconſiderable objects in the heavens, and of which the greater part of mankind have no occaſion to take any notice during the whole courſe of their lives, ſhe has, to talk in the hyperbolical language of Tycho Brahé, moved the earth from its foundations, ſtopt the revolution of the firmament, made the ſun ſtand ſtill, and ſubverted the whole order of the univerſe.

"Such were the advantages of this new hypotheſis, as they appeared to its author when he firſt invented it. But though that love of paradox, ſo natural to the learned, and that pleaſure which they are ſo apt to take in exciting, by the novelty of their ſuppoſed diſcoveries, the amazement of mankind, may, notwithſtanding what one of his diſciples tells us to the contrary, have had its weight in prompting Copernicus to adopt this ſyſtem; yet when he had completed his Treatiſe of Revolutions, and began coolly to conſider what a ſtrange doctrine he was about to offer to the world, he ſo much dreaded the prejudice of mankind againſt it, that, by a ſpecies of continence, of all others the moſt difficult to a philoſopher, he detained it in his cloſet for thirty years together. At laſt, in the extremity of old age, he allowed it to be extorted from him, but died as ſoon as it was printed, and before it was publiſhed."

This noble theory, however, being repugnant to the prejudices of habit and education, was at firſt coldly received, or utterly rejected, by every claſs of men. The aſtronomers alone favoured it with their notice, though rather as a convenient hypotheſis than an important truth. By the vulgar it was conſidered as a chimera, belied by the cleareſt evidence of our ſenſes; while the learned beheld it with diſdain, becauſe it militated againſt the fanciful diſtinctions and the vague erroneous tenets of the Peripatetic philoſophy, which no one had ventured to call in queſtion. And it is amuſing to obſerve with what dexterity the Copernicans, ſtill uſing the ſame weapons, endeavoured to parry the blows of their antagoniſts. Its real merits and blemiſhes appear to have been overlooked by both parties. Brahé framed a ſort of intermediate ſyſtem; but this Daniſh aſtronomer was more remarkable for his patience and ſkill in obſerving the heavens, than for his talents of philoſophical inveſtigation. Towards the commencement of the 16th century, a new order of things emerged. The ſyſtem of Copernicus became generally known and daily made converts. Its reception alarmed the ever-watchful authority of the church, rouſed her jealouſy, and at length provoked her vindictive artillery. The *ultima ratio theologorum* was pointed at the head of the illuſtrious Galileo, whoſe elegant genius diſcovered the laws of motion, extended the ſcience of mechanics, and added luſtre and ſolidity to the true ſyſtem of the univerſe. From the ſtorms of perſecution Copernicus himſelf had been exempted only by a timely death.

COPPER, one of the metals; for the properties of which, ſee Chemistry-*Index* in this Supplement.—

The Chineſe have a metal which they call *pe-tung*, but which Sir George Staunton denominates

White Copper. This metal has a beautiful ſilver-like appearance and a very cloſe grain. It takes a fine poliſh, and many articles of neat workmanſhip, in imitation of ſilver, are made of it. An accurate analyſis has determined it to conſiſt of copper, zinc, a little ſilver; and in ſome ſpecimens a few particles of iron and of nickel have been found. From this account it would appear that white copper is not an artificial mixture of metals, but is found native in the mine. Yet in the very ſame page and paragraph Sir George proceeds to ſay that Dr Gillan was informed at Canton, that the artiſts, in making their pe-tung, reduce the copper into as thin ſheets or laminæ, as poſſible, which they make red hot, and increaſe the fire to ſuch a pitch as to ſoften in ſome degree the laminæ, and to render them ready almoſt to flow. In this ſtate they are ſuſpended over the vapour of their pureſt tu-te-nag, or zinc, placed in a ſubliming veſſel over a briſk fire. The vapour thus penetrates the heated laminæ of the copper, ſo as to remain fixed with it, and not to be eaſily diſſipated or calcined by the ſucceeding fuſion it has to undergo. The whole is ſuffered to cool gradually, and is then found to be of a brighter colour, and of a cloſer grain, than when prepared in the European way. Surely this is not the white copper which conſiſts of copper, zinc, ſilver, iron and nickel.

Copper Mine, a large river of New-Britain, reckoned to be the moſt northern in North-America. Taking a northerly courſe it falls into the ſea in lat. 72. N. and about 119. W. long. from Greenwich. The accounts brought by the Indians of this river to the Britiſh ports in Hudſon bay, and the ſpecimens of copper produced by them, induced Mr Hearne to ſet out from Fort Prince of Wales in Dec. 1770, on a journey of diſcovery. He reached the river on the 14th July, at 40 miles diſtance from the ſea, and found it all the way incumbered with ſhoals and falls, and emptying itſelf into it over a dry flat of the ſhore, the tide being then out, which ſeemed by the edges of the ice to riſe about 12 or 14 feet. This riſe, on account of the falls, will carry it but a very ſmall way within the river's mouth; ſo that the water in it has not the leaſt brackiſh taſte. Mr Hearne had the moſt extenſive view of the ſea, which bore N. W. by W. and N. E.; when he was about 8 miles up the river. The ſea at the river's mouth, was full of iſlands and ſhoals; but the ice was only thawed away about ¾ths of a mile from the ſhore, on the 17th of July. The Eſquimaux had a quantity of whale bone and ſeal ſkins at their tents on the ſhore.—*Morſe.*

COQUIMBO, a town of St Jago, or Chili Proper, in S. America, ſituated at the lower end of the vale, bearing the ſame name, on a gently riſing ground. The river of Coquimbo gives name to the agreeable valley through which it rolls to the ſea; and the bay at its mouth is a very fine one, where ſhips lie ſafely and commodiouſly, though the coaſt is rocky, ſome iſlands lying ſo as to keep off the winds. The town is properly called *La Serena*, from the agreeableneſs of the climate; being continually ſerene and pleaſant. The ſtreets are well laid out, and there are 5 or 6 convents; but the houſes are not handſome. The ſoil is fruitful in corn, wine, and oil, and the brooks bring down quantities of gold duſt after heavy rains. Here are no gold mines, but plenty of copper; one of which, 5 leagues N. from the city on Mount Cerro Verde, or Green Hill, is high, and ſhaped like a ſugar loaf; ſo that it may ſerve as a land mark to the port. It lies 260 miles N. of St Jago, and juſtly boaſts of one of the fineſt ſituations in the world; but the arbitrary government of Spain renders it a place of little importance.—*ib.*

CORAL *River*, in New Mexico, runs a courſe W. by S. and empties into the head of the gulf of California, cloſe by the mouth of Collerado river.—*ib.*

CORAM, a poſt town in Suffolk co. Long Iſland, New-York. It has about 60 houſes, and lies 62 miles eaſtward of New-York city, and 10 from Smithtown.—*ib.*

CORCAS, or *Grand Corcas*, an iſland almoſt in the form of a creſcent, N. of St Domingo, in the windward paſſage, about 7 leagues W. of Turk's Iſland, and about 20 E. of Little Inagua, or Heneagua. N. lat. 21. 55. W. long. 70. 55.—*ib.*

CORDOVA, DE LA NUEVA ANDALUSIA, a city of Peru, in S. America, in the juriſdiction of Charcas, 80 leagues S. of Santiago del Eſtero. Here is the Epiſcopal church of Tucuman, with ſome monaſteries, and a convent. It is fruitful in grain, honey, wax, fruits, cotton, and ſugar. It abounds with ſalt-pits, and has luxuriant paſtures for mules. It drives a great trade with Buenos Ayres. The inhabitants are Spaniards, who are farmers and manufacturers of cotton cloth, which they ſend to Potoſi. S. lat. 31. 30. W. long. 63. 30. In Cordova, in the Tucuman, there has been found the greateſt inſtance of longevity ſince the days of the patriarchs. From indiſputable evidence, a negreſs, named Louiſa Truxo, was alive in 1774, aged *one hundred and ſeventy-five years.*—*ib.*

CORE *Sound*, on the coaſt of North-Carolina, lies S. of, and communicates with Pamlico.—*ib.*

CORIENTES, a cape of Mexico, or New-Spain, on the N. Pacific ocean. N. lat. 21. W. long. 109. 30. Alſo, the name of the S. weſternmoſt point of the iſland of Cuba.—*ib.*

Corientes, Los, a ſmall city within the government of Buenos Ayres, in S. America, was built by the Spaniards on the confluence of the Parana and Paraguay, 80 leagues higher than Santa Fe, on the Rio de la Plata.—*ib.*

CORINTH, a townſhip in Orange co. Vermont, W. of Bradford, containing 578 inhabitants.—*ib.*

CORK is the exterior bark of a tree which has been deſcribed in the Encyclopædia. When the tree is about 15 years old it is fit to be barked, and this can be done ſucceſſively for eight years. The bark always grows up again, and its quality improves as the age of the tree increaſes. It is commonly ſinged a little over a ſtrong fire or glowing coals, or laid to ſoak a certain time in water, after which it is placed under ſtones in order to be preſſed ſtraight. We were wont to procure the greater part of our cork from the Dutch, who brought it principally from France; but they imported ſome alſo from Portugal and Spain.

This tree, as well as the uſes to which its bark is put, was known to the Greeks and the Romans; by the former of whom it was called φελλος, and by the latter *ſuber*. By the Romans, as we learn from Pliny, it was even employed to ſtop veſſels of every kind; but its application to this uſe ſeems not to have been very common till the invention of glaſs bottles, of which Profeſſor Beckmann finds no mention before the 15th century.

In later times, ſome other vegetable productions have been found which can be employed inſtead of cork for the laſt mentioned purpoſe. Among theſe is the wood of a tree common in South America, particularly in moiſt places, which is called there *monbin* or *monbain*, and by botaniſts *ſpondias lutea*. This wood is brought to England in great abundance for that uſe. The ſpongy root of a North American tree, known by the name of *nyſſa*, is alſo uſed for the ſame end, as are the roots of liquorice, which on that account is much cultivated in Sclavonia, and exported to other countries.

CORNISH, a townſhip in Cheſhire co. New-Hampſhire, on the E. bank of Connecticut river, between Claremont and Plainfield, about 15 miles N. of Charleſtown, and 16 S. of Dartmouth College. It was incorporated in 1763. In 1775, it contained 309, and in 1790—982 inhabitants.—*Morſe*.

CORNUA Ammonis, in natural hiſtory, are foſſil ſhells, of which a pretty full account is given in the Encyclopædia. See Cornu *Ammonis* and Snake-*Stones*. It was obſerved, in the laſt of theſe articles, that few, if any, of theſe ſhells are known in their recent ſtate, or as occupied by the living animal; but ſome authors have aſſerted on the authority of Linnæus, that *ammonites*, with ſhells, ſimilar to all the varieties of the foſſil ones, are yet found alive in the depth of the ſea. We are much inclined to embrace this opinion; but it has been controverted by *M. de Lamanon*, who accompanied *La Perouſe* on his voyage of diſcovery, by ſuch arguments as we know not how to anſwer. This unfortunate naturaliſt (ſee Lamanon in this Supplement) allows that there are ſtill in the ſea living *cornua ammonis*; but he thinks that they are in very ſmall numbers, and materially different from the greater part of the foſſil ones. According to him, theſe laſt ought to be conſidered as a race, formerly the moſt numerous of all, of which, either there are no deſcendants, or thoſe deſcendants are reduced to a few degenerate individuals. That there are no living animals with ſhells of the very ſame kind with ſome of the foſſil *cornua ammonis*, the following obſervations he conſiders as a ſufficient proof.

“ The foſſil ſhells are very light and thin, whereas the ſhells of thoſe animals that live in very deep water are always thick and ponderous; beſides, the form of the foſſil cornua ammonis points out to us, in ſome meaſure, the organization of the animal which inhabited it. The celebrated Juſſieu proved, in 1721, that there exiſted a very cloſe analogy between the ammonite and nautilus (a). It is well known that the nautilus, by filling or emptying a part of its ſhell, has the power of remaining ſtationary in any depth it pleaſes: the ſame was doubtleſs the caſe with the ammonite; and if this ſpecies ſtill abounds in the ſea, it would ſurely be occaſionally diſcovered by ſailors.

“ The waves alſo would throw fragments of it on the ſhore; fiſhermen might ſometimes entangle it in their nets; or, at leaſt, there would be fragments ſticking to the lead of the ſounding line when aſcertaining great depths. It may alſo be added, that if the ammonites never quitted the abyſs of the ſea, thoſe which are found petrified would not be conſtantly met with on the ſame level, and in the ſame bed, as thoſe ſhell fiſh that only inhabit the ſhallows. There are, however, found in Normandy, Province, Touraine, and a multitude of other places, ammonites mixed with turbines, buccina (whelks), and other littoral ſhells. They are found, beſides, at every degree of elevation from below the level of the ſea to the ſummits of the higheſt mountains. Analogy alſo leads us to ſuppoſe, that Nature, who has given eyes to the nautilus, has not refuſed them to the ammonite; now what uſe could theſe be of if they remained confined to thoſe depths which the light is unable to penetrate?

“ The extinction of the ancient race of ammonites is therefore an eſtabliſhed fact, which no rational ſuppoſition can deſtroy; and this fact is undoubtedly the moſt ſurpriſing of any that is preſented to us in the hiſtory of aquatic animals. The diſcovery of a few living ſpecies of cornua ammonis does not deſtroy the truth of this, for theſe ammonites are very different from thoſe which are found petrified. They are extremely rare, and cannot be looked up to as the repreſentatives of the old ammonites, ſo varied in their ſpecies, and the number of which in the ancient ocean was probably far more conſiderable than that of all the other ſhells beſides.”

To every univalve ſhell, rolled in a ſpiral, ſo as that a horizontal plane will divide it into two equal parts, formed of united ſpirals, and bearing a certain proportion to each other, our author gives the name of an *ammonite*. “ I thought it abſolutely neceſſary (ſays he) to aſcertain the preciſe meaning of the term *ammonite*, previous to deſcribing that which I found during our voyage round the world. The form of this is almoſt orbicular, the long diameter being to the ſhort one as three lines to two lines and three quarters. The firſt ſpire is by far the largeſt, occupying nearly half of the longitudinal diameter. The ſummit is placed at the diſtance of about two-thirds of this diameter; it is terminated on the right ſide by a very ſmall knob viſible only through a magnifier, thus differing from the ammonite of Rimini, which beſides is microſcopical and celled, the inſide of this which we are now ſpeaking of being entirely plain. The number of ſpiral circumvolutions is four and a half; they are equally convex on both ſides, and are fixed on a plane, dividing the ſhell into two equal parts: there is on each ſide a kind of boſs formed by the increaſe of the perpendicular diameter of the ſpires, in proportion as they recede from the centre. The ſurface is ſmooth; the back is armed with a flat, even, brittle creſt, as thin as paper, ſurrounding it on every ſide like a ruff; it is about half a line broad, extends over the ſummit of the ſpires, and ſerves to join them together. The mouth of the ſhell is nearly triangular; its edges project in the form of lips, and are rounded at the border. I have often found this ammonite encloſed in the ſtomach of the bonetta (ſcomber pelamis, Linn.), caught in the South Sea, between the tropics, where no bottom was found with a line of more than two hundred fathoms. Theſe ſhells were covered with a black clayey mud. Their ſize varies from one to four lines acroſs; they are conſequently the largeſt living ammonites that have yet been diſcovered."

(a) There are, however, ſome ſtriking internal differences: firſt, the partitions in the ſhell of the nautilus are more curved than thoſe of the ammonite: ſecondly, the ammonite wants the ſmall hole which communicates from one cell to the other.

It is well known for what purpoſe the modern philoſophers of France have been ſo indefatigable in the ſtudy of natural hiſtory; and there can be little doubt but that it is to ſerve the ſame purpoſe that Lamanon thus reaſons for the deſtruction of the ancient race of ammonites in ſome univerſal convulſion of the world. But ſuppoſing his arguments concluſive, they affect not the truth of the Jewiſh and Chriſtian ſcriptures. It is nowhere ſaid in the Bible, that the *matter* of this globe was brought into being at the moment when Moſes repreſents the Creator as beginning to reduce the chaos into order; and it is more than inſinuated that there will be a *new earth* after the preſent ſyſtem of things ſhall be diſſolved. That *new* earth will certainly be ſtored with ſome kind of inhabitants; and could it be demonſtrated that there was an *old* earth, previous to the era of the Moſaic coſmogony, inhabited by creatures rational and irrational, and that the foſſil *cornua ammonis* make part of the wreck of that ſyſtem, the cauſe of revelation would remain uninjured. "Moſes, as a real philoſopher* has well obſerved, writes the hiſtory, not of this globe through all its revolutions, but of the race of Adam."

rofeſſor inſon of nburgh.

This ſecret attack, therefore, made by Lamanon againſt that religion of which he once profeſſed to diſcharge the duties of a prieſt, is nothing more than *telum imbelle ſine ictu*. Yet it may be worth ſome naturaliſt's while to enquire, whether, though feeble, it has been fairly made. We confeſs that our own ſuſpicions of unfair dealing are ſtrong; for when a man of ſcience contradicts himſelf in the courſe of two pages, the blunder muſt be attributed to ſome other ſource than mere inadvertency. M. de Lamanon wiſhes to prove, among other things, that the ancient ammonites did not inhabit great depths of the ſea; and that Linnæus was miſtaken when he ſuppoſed that in great depths they may ſtill be found. Yet he himſelf tells us, that he frequently caught ammonites in the South Sea, where no bottom was to be found with a line of *more than* 200 *fathoms*; and to put it beyond a doubt that the animals had been at that bottom, he informs us, that their ſhells were covered with a *black clayey mud*. It is true theſe ammonites were but ſmall; while of 300 varieties of foſſil ammonites which he mentions, ſome, he ſays, have been found ten feet in circumference. But is it certain that theſe large ſhells were real *cornua ammonis*? If they agree not exactly with our author's deſcription of the ſhell of the ammonite (a fact into which we have had no opportunity of inquiring), his arguments for the extinction of the ancient race are groſs ſophiſms, unworthy of a man either of ſcience or of candour.

CORNWALL, a townſhip in Addiſon co. Vermont, E. of Bridport, on Lake Champlain, containing 826 inhabitants.—*Morse.*

CORNWALL, NEW, a townſhip in Orange co. New-York, of whoſe inhabitants, 350 are electors.—*ib.*

CORNWALL, a townſhip in Litchfield co. Connecticut, about 9 miles N. of Litchfield, 11 S. of Saliſbury, and about 40 W. by N. of Hartford city.—*ib.*

CORNWALL, a ſmall town in Upper Canada, on the bank of Iroquois river near Lake St Francis, between Kingſton and Quebec, containing a ſmall church, and about 30 or 40 houſes.—*ib.*

CORNWALLIS, a town in King's co. in the province of New-Brunſwick, ſituated on the S. W. ſide of the Baſin of Minas; 18 miles N. W. of Falmouth, and 55 N. W. of Annapolis.

Alſo, a river in the ſame province, navigable for veſſels of 100 tons 5 miles; for veſſels of 50 tons 10 miles.—*ib.*

CORO, a town of S. America, in Terra Firma, at the bottom of the gulf of Venezuela, 60 miles W. of La Guaira. N. lat. 11. W. long. 70.—*ib.*

COROPA, a province of S. America, ſituated between the river Amazon and the lake Parime.—*ib.*

CORRECTION-HOUSE is a priſon where idle vagrants are compelled to work, and where perſons guilty of certain crimes ſuffer puniſhment and make reparation to the public. Of the former kind of *correction-houſes*, perhaps enough has been ſaid in the Encyclopædia under the title WORK-*Houſe*; but of the latter very little will be found in that work under the titles BRIDEWELL and IDLENESS.

Perhaps houſes of correction, as means of puniſhment, are not, in this country, employed ſo frequently as juſtice and expediency ſeem to require. In the opinion of Dr Paley, whoſe opinions are always worthy of attention, it is one of the greateſt defects of the laws of England (and we may ſay the ſame thing of the laws of Scotland), that "they are not provided with any other puniſhment than that of death, ſufficiently terrible to keep offenders in awe. Tranſportation, which is the puniſhment ſecond in the order of ſeverity, anſwers the purpoſe of example very imperfectly; not only becauſe exile is in reality a ſlight puniſhment to thoſe who have neither property, nor friends, nor regular means of ſubſiſtence at home, but becauſe the puniſhment, whatever it be, is unobſerved and unknown. A tranſported convict *may* ſuffer under his ſentence, but his ſufferings are removed from the view of his countrymen; his miſery is unſeen; his condition ſtrikes no terror into the minds of thoſe for whoſe warning and admonition it was intended. This chaſm in the ſcale of puniſhment produces alſo two farther imperfections in the adminiſtration of penal juſtice; of which the firſt is, that the ſame puniſhment is extended to crimes of very different characters and malignancy; and the ſecond, that puniſhments, ſeparated by a great interval, are aſſigned to crimes hardly diſtinguiſhable in their guilt and miſchief."

Perhaps this chaſm might be properly filled up by houſes of correction under judicious management, which might likewiſe promote another important purpoſe, better than the puniſhments in common uſe.

The end of puniſhment is twofold, *amendment* and *example*. In the firſt of theſe, the *reformation* of criminals, little has ever been effected, and little indeed ſeems practicable by the puniſhments known to the laws of Britain. From every ſpecies of puniſhment inflicted among us, from impriſonment and exile, from pain and infamy, malefactors return more hardened in their crimes, and more inſtructed. The caſe we think would often be different when they returned to the world from a well-regulated houſe of correction. As experience is the only ſafe guide in matters of legiſlation and police, we ſhall lay before our readers *M. Thouin's* account of the houſe of correction at Amſterdam, which ſeems to corroborate our opinion.

The Amſterdam correction houſe, from the employment of the priſoners confined in it, is called the *raſping-houſe*, and is deſtined to the reception of thoſe malefactors whoſe crimes do not amount to a capital offence. Their puniſhment cannot ſo properly be denominated ſolitary confinement as a ſequeſtration from ſociety during a limited term of years. The building is ſituated in a part of the ſuburbs to the north eaſt of the city. The exterior has nothing remarkable, either with reſpect to form or extent. It is detached from the ſtreet by a ſpacious court, which contains the keeper's lodge, together with apartments for the different ſervants belonging to the eſtabliſhment. Over the gate, which opens from this court into the priſon, are placed two ſtatues, as large as life, repreſenting two men in the act of ſawing a piece of logwood.

The inner court is in the form of a ſquare, round which are arranged the apartments of the priſoners, together with the neceſſary warehouſes. One part of the ground ſtory is divided into different chambers; the other ſerves as a depot for the logwood, and the implements employed in its preparation.

The keeper, whoſe countenance, contrary to the general cuſtom of perſons of his profeſſion, was ſtrongly indicative of urbanity and gentleneſs, introduced M. Thouin into an apartment where two priſoners were at work in ſawing a large log of Campeachy wood. The ſaw is compoſed of four blades joined together, with very ſtrong, large, and ſharp teeth, which make a ſciſſure in the wood of nearly two inches in breadth. The operation is repeated, till the pieces become too ſmall to undergo the ſaw, when they are ground in mills peculiarly conſtructed for this purpoſe.

This employment requires an extraordinary exertion of ſtrength, and is at firſt a ſevere penance even to robuſt perſons; but habit, addreſs, and practice, ſoon render it eaſy; and the priſoners in a ſhort time become competent to furniſh, without painful exertion, their weekly contingent of 200lb. weight of ſawed pieces. After completing this taſk, they even find time to fabricate a variety of little articles in wood and ſtraw, which they ſell to thoſe who viſit the priſon, or diſpoſe of, by means of agents, in the town.

M. Thouin next inſpected three apartments of different dimenſions, which opened into the inner court. The one was inhabited by four, the ſecond by ſix, and the third by ten priſoners. The furniture of the rooms conſiſted in hammocks, with a matraſs, a blanket, and a coverlid to each, tables, chairs, and ſtools, glaſs, &c. earthen veſſels, and various other articles of convenience. Every thing in theſe apartments was diſtinguiſhed by neatneſs and propriety; and notwithſtanding the number of inhabitants allotted to each, was fully adequate to the dimenſions of the rooms; the ſenſes were not offended with any diſagreeable ſcent, and the air was in every reſpect as pure and wholeſome as the ſurrounding atmoſphere.

In an obſcure part of the building are a number of cells, in which formerly thoſe priſoners who revolted againſt the proper ſubordination of the place, or ill-treated their comrades, were confined for a few days. But the keeper aſſured M. Thouin that theſe cells had not been made uſe of for upwards of 10 years. They are dark gloomy dungeons, with only a ſmall aperture for the admiſſion of light and air. The ſuppreſſion of this barbarous and coercive puniſhment does honour to the humanity of government.

The ſtore-rooms are filled with various kinds of wood for the purpoſes of dyeing; as the haemotoxylum campechianum, the morus tinctoria, the caeſalpinia ſappan, &c. They are all exotics, with the exception of the Evonymus Europæus. The warehouſes were not of ſufficient extent to contain the quantity of wood, which was depoſited in piles in different parts of the court.

The priſoners, amounting to 76 in number, were uniformly habited in coarſe woollens; wear very good ſtockings, large leather ſhoes, white ſhirts, and caps or hats. They are, by the rules of the houſe, obliged to frequent ablutions, which greatly contribute to the preſervation of their health. There was only one ſick perſon among them; and, what is not a little remarkable, almoſt all the priſoners had formerly lived in large commercial towns; very few villagers were amongſt them. They had all been ſentenced to impriſonment for theft; but it depends upon themſelves, by reformation and good behaviour, to ſhorten the term of their confinement, which many of them frequently do.

The keeper, whoſe humanity to the unfortunate perſons committed to his care intitles him rather to the title of their protector than their gaoler (and M. Thouin informs us, that the priſoners generally called him by no other name than *father),* aſſiſts them with his counſels and friendly admonitions. He regiſters every week, in a book appropriated to this purpoſe, both the inſtances of good and bad behaviour, which is annually ſubmitted to the examination of the magiſtracy, who, from this report, abridge or prolong the term of confinement according to the degree of indulgence which each priſoner appears to merit. Caſes frequently happen, where a malefactor, condemned to an impriſonment of eight years, by his good behaviour procures his enlargement at the expiration of four; and ſo in proportion for a ſhorter term. But great attention is paid to diſcriminate between actual reform and hypocritical artifice.

The reward of good behaviour is not, however, confined to, or withheld till, the period of actual liberation. Their reſtoration to ſociety is preceded by a progreſſive amelioration of their lot. Their work is gradually rendered leſs laborious, they are accommodated with ſeparate apartments, and employed in the ſervices of domeſtic economy- .The keeper even entruſts them with commiſſions beyond the precincts of the priſon; and ſcarce a ſingle inſtance has occurred of their abuſing this indulgence. By this prudent management, a conſiderable ſaving is effected in the expence of the eſtabliſhment, at the ſame time that it tends to wear away prejudice, and to initiate the priſoners, by gradual advances, into the reciprocal duties of ſocial life.

M. Thouin made particular inquiries whether it was cuſtomary the former, and 4 N. W. of the latter. N. lat. 18. 12.—*ib.*

COTOPAXI, a large volcano near Lataacungo, an aſſiento or dependence on the province of Quito, in Peru, S. America. It lies nearly under the line, yet the tops of it are generally covered with ice and ſnow. It firſt ſhewed itſelf in 1553, when Sebaſtian de Belacazar firſt entered theſe countries, which eruption proved favourable to his enterpriſe, as it coincided with a prediction of the Indian prieſts, that the country ſhould be invaded on the burſting of this volcano; and accordingly it ſo happened; for before 1559 he had ſubdued all the country.—*ib.*

COTUY, a canton and town in the Spaniſh part of the iſland of St Domingo, bounded E. by the bay of Samana, N. by the chain of mountains called Monte-Chriſti, W. by the territory of la Vega, and S. by the chain of mountains called Sévico. In 1505, the gold mines were worked here. In the mountain of Meymon, whence comes the river of the ſame name, there is a copper mine, ſo rich, that when refined will produce 8 per cent. of gold. Here are alſo found excellent lapis-lazuli, a ſtreaked chalk, that ſome painters prefer to bole for guilding; loadſtone, emeralds, and iron. The iron is of the beſt quality, and might be conveyed from the chain of Sévico by means of the river Yuna. The ſoil here is excellent, and the plantanes produced here are of ſuch ſuperior quality, that this manna of the Antilles is called at St Domingo Sunday plantanes. The people cultivate tobacco, but are chiefly employed in breeding ſwine. The inhabitants are called clowniſh, and of an unſociable character.

The town is ſituated half a league from the S. W. bank of the Yuna, which becomes unnavigable near this place, about 13 leagues from its mouth in the bay of Samana. It contains 160 ſcattered houſes, in the middle of a little ſavanna, and ſurrounded with woods, 30 leagues northerly of St Domingo, and 12 S. E. of St Yago. N. lat. 19. 11. W. long. from Paris 72. 27.—*ib.*

COUDRAS, a ſmall iſland in St. Lawrence river, about 45 miles N. E. of Quebec.—*ib.*

COUNTRY *Harbor*, ſo called, is about 20 leagues to the eaſtward of Halifax, in Nova-Scotia.—*ib.*

COUPEE', or *Cut Point*, a ſhort turn in the river Miſſiſſippi, about 35 miles above Mantchac fort, at the gut of Ibberville, and 259 from the mouth of the river. Charlevoix relates that the river formerly made a great turn here, and ſome Canadians, by deepening the channel of a ſmall brook, diverted the waters of the river into it, in the year 1722. The impetuoſity of the ſtream was ſuch, and the ſoil of ſo rich and looſe a quality, that in a ſhort time the point was entirely cut through, and the old channel left dry, except in inundations: by which travellers ſave 14 leagues of their voyage. The new channel has been ſounded with a line of 30 fathoms, without finding bottom.

The Spaniſh ſettlements of Point Coupeé, extend 20 miles on the W. ſide of the Miſſiſſippi, and there are ſome plantations back, on the ſide of La Fauſe Riviere, through which the Miſſiſſippi paſſed about 70 years ago. The fort at Point Coupeé is a ſquare figure, with four baſtions, built with ſtockades. There were, ſome years ſince, about 2000 white inhabitants and 7000 ſlaves. They cultivate Indian corn, tobacco, and indigo; raiſe vaſt quantities of poultry, which they ſend to New-Orleans. They alſo ſend to that city ſquared timber, ſtaves, &c.—*ib.*

COURTESEY of Scotland. See Law *(Encycl.)*, Part III. ſect ix § 28.

COVENTRY, a townſhip in Tolland co. Connecticut, 20 miles E. of Hartford city. It was ſettled in 1709, being purchaſed by a number of Hartford gentlemen of one Joſhua, an Indian.—*Morſe.*

Coventry, in Rhode-Iſland ſtate, is the N. eaſternmoſt townſhip in Kent co. It contains 2477 inhabitants.—*ib.*

Coventry, a townſhip in the northern part of New-Hampſhire, in Grafton co. It was incorporated in 1764, and contains 80 inhabitants.—*ib.*

Coventry, a townſhip in Orleans co. Vermont. It lies in the N. part of the ſtate, at the S. end of Lake Memphremagog. Black river paſſes through this town in its courſe to Memphremagog.—*ib.*

Coventry, a townſhip in Cheſter co. Pennſylvania.—*ib.*

COWE', is the capital town of the Cherokee Indians, ſituated on the foot of the hills, on both ſides of the river Tenneſſee. Here terminates the great vale of Cowé, exhibiting one of the moſt charming, natural, mountainous landſcapes that can be ſeen. The vale is cloſed at Cowé by a ridge of high hills, called the *Jore mountains*. The town contains about 100 inhabitants.

In the conſtitution of the ſtate of Tenneſſee, Cowé is deſcribed as near the line which ſeparates Tenneſſee from Virginia, and is divided from Old-Chota, another Indian town, by that part of the Great Iron or Smoaky mountain, called Unicoi, or Unaca mountain.—*ib.*

COWETAS, or *Kowetas*, a town of the Lower Creeks, in Eaſt-Florida, called the Bloody-town. It lies on the W. bank of Chata-Uche river and contains 280 men.—*ib.*

COWPENS, a place ſo called, in S. Carolina, between Pacolet river and the head branch of Broad river. This is the ſpot where Gen. Morgan gained a complete victory over lieut. col. Tarleton, Jan. 11, 1781, having only 12 men killed and 60 wounded. The Britiſh had 39 commiſſioned officers killed, wounded and taken priſoners; 100 rank and file killed, 200 wounded, and 500 priſoners. They left behind 2 pieces of artillery, 2 ſtandards, 800 muſkets, 35 baggage-waggons, and 100 dragoon horſes, which fell into the hands of the Americans. The field of battle was in an open wood.—*ib.*

COWRY-Shells, the loweſt money in ſome parts of the Eaſt. See Money *(Encycl.)*, where they are called *karis*.

COXHALL, a townſhip in York co. diſtrict of Maine, containing 775 inhabitants.—*Morſe.*

COXSAKIE, a townſhip in the weſtern part of Albany co. New-York, containing 3406 inhabitants, of whom 302 are ſlaves. Of the citizens 613 are electors.—*ib.*

COYAU, a ſettlement on Tenneſſee river, 30 miles below Knoxville.—*ib.*

CRAB-ORCHARD, a poſt town, on Dick's river, in Kentucky, 8 miles from Cumberland river, and 25 miles S. E. of Danville. The road to Virginia paſſes through this place.—*ib.*

CRANBERRY, a thriving town in Middleſex co. New-Jerſey, 9 miles E. of Princeton, and 16 S. S. W. of Brunſwick. It contains a handſome Preſbyterian church, and a variety of manufactures are carried on by its induſtrious inhabitants. The ſtage from New-York to Philadelphia paſſes through Amboy, this town, and thence to Bordentown.—*ib.*

CRANBERRY *Iſlands*, on the coaſt of the diſtrict of Maine.—*ib.*

CRANE, in mechanics, a machine uſed for raiſing or lowering great weights. For the principles on which theſe machines act, ſee DYNAMICS in this *Supplement*, and likewiſe MECHANICS, *Encycl.* where deſcriptions are given of ſeveral very powerful cranes.

The crane in common uſe is employed with ſome danger to thoſe who work it; and therefore a machine of this kind, acting upon a ſimple and certain principle, by which the men walking in the wheel can lower goods with ſafety as well as expedition, has long been conſidered as a great deſideratum in mechanics. Repeated premiums have been offered by the *Society for the Encouragement of Arts*, to induce ingenious men to attempt the invention of ſuch a machine; and various have been the contrivances for accompliſhing ſo deſirable a purpoſe. A clergyman, who ſubſcribes E. C. we ſuppoſe as the initials of his name, propoſes, through the medium of the Repertory of Arts, to accompliſh it merely by introducing the action of a worm or ſcrew into the crane.

Whenever a worm of two threads is introduced into a machine, all retrograde motion is ſtopped, unleſs that worm receive its reaction from the firſt moving force; for, powerfully as a worm acts upon a wheel, a wheel has no power upon a worm, whatever force may be applied to it. Suppoſe, then, the firſt motion in a crane were given by a worm upon the axis of the wheel in which the man walks, the man would have perfect command of the machine, to raiſe or lower the goods at pleaſure, with the remoteſt poſſibility of being overpowered by the deſcending weight.

"Were I to conſtruct (ſays the author) a crane upon this principle, I would have the axis of the wheel in which the man walks, and the axis of the worm, in ſeparate parts, and occaſionally united by a coupling-box, When goods were to be raiſed, the two axes ſhould be connected; when lowered, they might be diſunited, and the worm turned by a winch, which would be done much more expeditiouſly that way than by the wheel. For the reaſons before ſuggeſted, the deſcent of the weight could be accelerated or ſtopped at pleaſure, at the diſcretion of the perſon turning the winch.

"This contrivance might be not inconveniently applied to a crane already erected upon the common principle: Let there be a wheel put upon any convenient axis in the machine as it now ſtands; upon this let there lie a worm that can be thrown in or out of gear at pleaſure; and let the lever by which it is done lie within reach of the man's hand in the wheel. The goods being faſtened to the crane, and raiſed off the floor of the warehouſe ready for letting down, the man puts the worm into gear, leaves the wheel, and lets the goods down by the winch. Provided it can be conveniently done, it would be adviſable to throw the wheel in which the man walks out of gear, when the winch is made uſe of: this, however, I ſhould apprehend, would not be a matter of abſolute neceſſity."

Our author is aware of two objections which may be urged againſt the introduction of a worm into a crane in the manner which he propoſes. The firſt ariſes from the ſlowneſs of the motion produced by the turning of a ſcrew which he conſiders as unworthy of regard; becauſe the neceſſary ſpeed is to be gained by the firſt pair of wheels, and the diameter of the barrel of the windlaſs.

To the ſecond, ariſing from the ſuppoſed greater friction between a worm and wheel, he replies, that as the friction between the teeth of two wheels (if not formed on the true epicycloidal principle) muſt, while it laſts, be greater than between a worm and wheel for the ſame ſpace of time, it ſeems no unreaſonable ſuppoſition that the aggregate of friction will, in the two caſes, nearly balance each other; eſpecially if it be taken into the account, that to obtain the power of one worm and wheel, there will be, in moſt caſes, required two pair of wheels, and two additional axes—all which will add to the friction. But granting the balance of friction to be againſt the action of the worm, the power to overcome it is greater in proportion than to overcome the friction of two wheels.

Mr James Whyte of Chevening, in the county of Kent, whoſe improvement in the conſtruction of pullies, has with due reſpect been noticed elſewhere*, gives, in *the Tranſactions of the Society for the Encouragement of Arts*, &c. the following deſcription of a new crane for wharfs:

Plate XX.

A (fig. 1.), a circular inclined plane, moving on a pivot underneath it, and carrying round with it the axis E. A perſon walking on this plane, and preſſing againſt the lever B, throws off the gripe D, by means of an iron rod C; and thus admits the plane and its axis to move freely, and raiſe the weight G by the coiling of the rope F round the axis E.

To ſhew more clearly the conſtruction and action of the lever and gripe, a plan of the circular inclined plane, with the lever and gripe, is added (ſee fig. 2.), where B repreſents the lever, D the ſpring or gripe. In this plan, when the lever B is in the ſituation in which it now appears, the ſpring or gripe D preſſes againſt the periphery of the plane, as ſhewn by the double line, and the machine cannot move; but when the lever B is preſſed out to the dotted line H, the gripe is alſo thrown off to the dotted line I, and the whole machine left at liberty to move. One end of a rope or cord, of a proper length, is fixed near the end of the lever B, and the other end made faſt to one of the uprights, ſerving to prevent the lever moving too far when preſſed by the man.

The properties of this crane, for which the premium of 40 guineas was adjudged by the ſociety to the inventor, are as follows:

1. It is ſimple, conſiſting merely of a wheel and axle. 2. It has comparatively little friction, as is obvious from the bare inſpection of the figure. 3. It is durable, as is evident from the two properties above-mentioned. 4. It is ſafe; for it cannot move but during the pleaſure of the man, and while he is actually preſſing on the gripe-lever. 5. This crane admits of an almoſt infinite variety of different powers, and this variation is obtained without the leaſt alteration of any part of the

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* See Mechanics, n° 27. Encycl.

as the radii to the tangent lines on the faces of the ſtaff.—The inſtrument was uſed in taking the altitudes of the celeſtial bodies at ſea.

Cross *Cape*, in Upper Canada, projects from the N. E. ſide of St Mary's river, at the outlet of lake Superior, oppoſite the falls, in N. lat. 46. 30. W. long. 84. 50.—*Morse.*

Cross-Creek, a townſhip in Waſhington county, Pennſylvania.—*ib.*

Cross-Roads, the name of a place in North-Carolina, near Duplin court-houſe, 23 miles from Sampſon court-houſe, and 23 from South-Waſhington.—*ib.*

Cross-Roads, a village in Kent co. Maryland, ſituated 2 miles S. of Georgetown, on Saſſafras river, and is thus named from 4 roads which meet and croſs each other in the village.—*ib.*

Cross-Roads, a village in Cheſter co. Pennſylvania, where 6 different roads meet. It is 27 miles S. E. of Lancaſter; 11 N. by W. of Elkton, in Maryland, and about 18 W. N. W. of Wilmington in Delaware.—*ib.*

CROSSWICKS, a village in Burlington co. New-Jerſey; through which the line of ſtages paſſes from New-York to Philadelphia. It has a reſpectable Quaker meeting-houſe; 4 miles S. W. of Allen Town, 8 S. E. of Trenton, and 14 S. W. of Burlington.—*ib.*

CROTON *River*, a N. eaſtern water of Hudſon river, riſes in the town of New-Fairfield, in Connecticut, and running through Dutcheſs co. empties into Tappan bay. Croton bridge is thrown over this river 3 miles from its mouth, on the great road to Albany. This is a ſolid ſubſtantial bridge, 1400 feet long, the road narrow, piercing through a ſlate hill. It is ſupported by 16 ſtone pillars. Here is an admirable view of Croton Falls, where the water precipitates itſelf between 60 and 70 feet perpendicular; high ſlate banks, in ſome places 100 feet; the river ſpreading into three ſtreams, as it enters the Hudſon.—*ib.*

CROW *Creek*, falls into the Tenneſſee, from the N. W. oppoſite the Crow Town, 15 miles below Nickajack Town.—*ib.*

CROWN, *in aſtronomy*, a name given to two conſtellations, the ſouthern and the northern.

Crown, *in geometry*, a plane ring included between two parallel or concentric peripheries of unequal circles.

Crown-Poſt, is a poſt in ſome buildings ſtanding upright in the middle between two principal rafters; and from which proceed ſtruts or braces to the middle of each rafter. It is otherwiſe called a *king poſt*, or *king's-piece*, or *joggle-piece*.

Crown *Point*, is the moſt ſoutherly townſhip in Clinton co. New-York, ſo called from the celebrated fortreſs, which is in it, and which was garriſoned by Britiſh troops, from the time of its reduction by gen. Amherſt in 1759, till the late revolution. It was taken by the Americans the 14th of May 1775, and retaken by the Britiſh the year after. The point upon which it was erected, by the French in 1731, extends N. into lake Champlain. It was called *Kruyn Punt*, or *Scalp Point*, by the Dutch, and by the French, *Pointe à la Cheveleure*. The fortreſs they named Fort St Frederick. After it was repaired by the Britiſh, it was the moſt regular and expenſive of any conſtructed by them in America. The walls are of wood and earth, about 16 feet high and about 20 feet thick, nearly 150 yards ſquare, and ſurrounded by a deep and broad ditch, dug out of the ſolid rock. The only gate opened on the N. towards the lake, where was a draw-bridge and a covert-way, to ſecure a communication with the waters of the lake, in caſe of a ſiege. On the right and left, as you enter the fort, is a row of ſtone barracks, not inelegantly built, which are capable of containing 2000 troops. There were formerly ſeveral out-works, which are now in ruins, as is indeed the caſe with the principal fort, except the walls of the barracks. The famous fortification called Ticonderoga is 15 miles S. of this; but that fortreſs is alſo ſo much demoliſhed, that a ſtranger would ſcarcely form an idea of its original conſtruction. The town of Crown Point has no rivers; a few ſtreams, however, iſſue from the mountains, which anſwer for mills and common uſes. In the mountains, which extend the whole length of lake George, and part of the length of lake Champlain, are plenty of mooſe, deer, and almoſt all the other inhabitants of the foreſt. In 1790, the town contained 203 inhabitants. By the ſtate cenſus of 1796, it appears there are 126 electors. The fortreſs lies in N. lat. 44. 20. W. long. 73. 36.—*Morse.*

CROWS *Meadows*, a river in the N. W. territory, which runs N. weſtward into Illinois river oppoſite to which are fine meadows. Its mouth is 20 yards wide, and 240 miles from the Miſſiſſippi. It is navigable between 15 and 18 miles.—*ib.*

CROYDEN, a townſhip in Cheſhire co. New-Hampſhire, adjoining Corniſh, and about 18 miles N. E. of Charleſtown. It was incorporated in 1763. In 1775, it contained 143, and in 1790, 537 inhabitants.—*ib.*

CRUCES, a town of Terra Firma, S. America, 5 leagues from Panama, and ſituated on Chagre river.—*ib.*

La CRUZ, an excellent harbour on the north-weſt coaſt of America, diſcovered by the Spaniards in 1779. They were introduced into it by a paſſage which they called *Bucarelli's entrance*, and which they placed in 55° 18′ N. Lat. and 139° 15′ W. Long. from the meridian of Paris. There is no good reaſon to queſtion the exactneſs of the latitude of this paſſage as laid down by the Spaniards; but the editor of Perouſe's voyage juſtly concludes, from the ſurvey made by our celebrated navigator Captain Cook on the coaſts adjacent to the entrance of Bucarelli, that this entrance is about 135° 20′ to the weſt of Paris, or very nearly 133° weſt of Greenwich.

The Spaniards were not long in the harbour of *La Cruz* before they received a viſit from the inhabitants in its neighbourhood. Bartering took place. The Indians gave their peltry, and various trifles, for glaſs beads, bits of old iron, &c. By this traffic the Spaniards were enabled to gain a ſufficiently exact knowledge of their genius, of their offenſive and defenſive arms, of their manufactures, &c.

Their colour is a clear olive; many among them have, however, a perfectly white ſkin: their countenance is well proportioned in all its parts. They are robuſt, courageous, arrogant, and warlike.

They clothe themſelves in one or two undreſſed ſkins (with the fur apparently); theſe are the ſkins of otters, of ſea-wolves, of benades (a ſpecies of deer), of bears, or other animals, which they take in hunting. Theſe dreſſes cover them from the neck to the middle of the leg ; there are, however, many among them who wear boots of ſmooth ſkin, reſembling Engliſh boots, only that thoſe of the Indians open before, and are laced tight with a ſtring. They wear hats woven from the fine bark of trees, the form of which reſembles that of a funnel or a cone. At the wriſts they have bracelets of copper or iron, or for want of theſe metals the fins of whales ; and round the neck, necklaces of ſmall fragments of bones of fiſhes and other animals, and even copper collars of the bigneſs of two fingers. They wear in their ears pendants of mother of pearl, or flat pieces of copper, on which is emboſſed a reſin of a topaz colour, and which are accompanied with jet beads. Their hair is long and thick, and they make uſe of a comb to hold it together in a ſmall queue from the middle to the extremity ; a narrow ribbon of coarſe linen, woven for this purpoſe, ſerves as a ligament. They wear alſo as a covering a kind of ſcarf, woven in a particular manner, ſomething more than a yard and a half long, and about half a yard broad, round which hangs a fringe ſomething more than half a quarter of a yard deep, of which the thread is regularly twiſted.

The women give proofs of their modeſty and decency by their dreſs. Their phyſiognomy is agreeable, their colour freſh, their cheeks vermilioned, and their hair long ; they plait it together in one long treſs. They wear a long robe of a ſmooth ſkin tied round the loins, like that of a nun ; it covers them from the neck as low as the feet ; the ſleeves reach down to the wriſts. Upon this robe they put divers ſkins of otters or other animals to defend themſelves from the inclemency of the weather. Better dreſſed, many of them might diſpute charms with the moſt handſome Spaniſh women ; but diſſatisfied with their natural charms, they have recourſe to art, not to embelliſh, but to disfigure themſelves. All the married women have a large opening in the under lip, and this opening or orifice is filled up by a piece of wood cut in an oval ſhape, of which the ſmalleſt diameter is almoſt an inch ; the more a woman is advanced in years the more this curious ornament is extended : it renders them frightful, the old women eſpecially, whoſe lip, deprived of its wonted ſpring, and dragged by the weight of this extraordinary jewel, neceſſarily hangs in a very diſagreeable manner. The girls wear only a copper needle, which croſſes the lip in the place where the ornament is intended hereafter to be placed.

Theſe Indians in war make uſe of cuiraſſes and ſhoulder pieces of a manufacture like that of the whalebone ſtays among the Europeans. Narrow boards or ſcantlings form, in ſome ſort, the woof of the texture, and threads are the warp : in this manner the whole is very flexible, and leaves a free uſe to the arms for the handling of weapons. They wear round the neck a coarſe and large gorget which covers them as high as below the eyes, and their head is defended by a morion, or ſkull piece, uſually made of the head of ſome ferocious animal. From the waiſt downwards, they wear a kind of apron, of the ſame contexture as their cuiraſs. Laſtly, a fine ſkin hangs from their ſhoulders down to the knee. With this armour, they are invulnerable to the arrows of their enemies ; but thus armed they cannot change poſition with ſo much agility as if they were leſs burdened.

Their offenſive arms are arrows ; bows, of which the ſtrings are woven like the large cords of our beſt muſical inſtruments ; lances four yards in length, tongued with iron ; knives of the ſame metal, longer than European bayonets, a weapon however not very common among them ; little axes of flint, or of a green ſtone, ſo hard that they cleave the moſt compact wood without injury to their edge.

The pronunciation of their language is extremely difficult ; they ſpeak from the throat, with a movement of the tongue againſt the palate ; the little uſe the women make of the inferior lip greatly injures the diſtinctiveneſs of their language ; the Spaniards could neither pronounce nor write the words which they heard.

From the vivacity of ſpirit in theſe Indians, and from their attention amply to furniſh the market eſtabliſhed in the harbour, it may be concluded that they are pretty laborious. They continually brought ſtuffs well woven and ſhaded by various colours, the ſkins of land and ſea wolves, of otters, bears, and other ſmaller animals ; of theſe ſome were raw, and others dreſſed. There were to be found at this market alſo coverlets of coarſe cloth, ſhaded with white and brown colours, very well woven, but in ſmall quantities : large ribbons of the ſame linen which might match with that of the Spaniſh officers mattreſſes ; ſkeins of thread ſuch as this cloth was made of ; wooden plates or bowls neatly worked ; ſmall boats or canoes painted in various colours, the figures of which repreſented heads with all their parts ; frogs in wood nicely imitated, which opened like tobacco boxes, and which they employed to keep their trinkets in : boxes made of ſmall planks, of a cubical form, being three quarters of a yard on each ſide, with figures well drawn, or carved on the outſide, repreſenting various animals ; the covers fabricated like Flanders etwees, with rabbeted edges, formed ſo as to ſhut into the body of the box ; animals in wood, as well thoſe of the earth as of the air : figures of men of the ſame material, with ſkull-caps repreſenting the heads of various fierce animals ; ſnares and nets for fiſhing ; copper collars for the neck, and bracelets of iron for the wriſt, but which they would not part with except at a very high price ; beak-like inſtruments, from which they drew ſounds as from a German flute. The principal officers took ſuch of theſe merchandizes as were moſt agreeable to them, and left the remainder to the ſhips crews.

As the Indians diſcovered that the Spaniards were very dainty in their fiſh, they did not let them want for choice : the greateſt abundance was in ſalmon, and a ſpecies of ſole or turbot three yards and a quarter long, broad and thick in proportion ; cod and pilchards were alſo brought to market, and fiſhes reſembling trout. From all this it may be inferred that this gulf is full of fiſh ; the banks too are covered with ſhells.

The quantity of mother-of-pearl that theſe Indians cut to pieces for making ear-rings awakened the curioſity of the Spaniards : they tried to diſcover whether theſe people had not in their poſſeſſion, or whether their country did not produce pearls, or ſome precious ſtones : their reſearches were fruitleſs, they only found ſome ſtones which they judged to be metallic, and which they carried on board, not having the neceſſary means for extracting the metal they might contain.

Theſe Indians feed upon fiſh, freſh or dry, boiled or roaſted ; herbs and roots which their mountains yielded them, ever after kept up a very cordial and friendly correſpondence; though, it is believed, they never from that time had a perſonal interview.

During the time that Cullen practiſed as a country ſurgeon and apothecary, he formed another connection of a more permanent kind, which, happily for him, was not diſſolved till a very late period of his life. With the ardour of diſpoſition he poſſeſſed, it cannot be ſuppoſed he beheld the fair ſex with indifference. Very early in life he took a ſtrong attachment to an amiable woman, a Miſs Johnſton, daughter to a clergyman in that neighbourhood, nearly of his own age, who was prevailed on to join with him in the ſacred bonds of wedlock, at a time when he had nothing elſe to recommend him to her except his perſon and diſpoſitions; for as to riches and poſſeſſions he had little of theſe to boaſt of. She was beautiful, had great good ſenſe, equanimity of temper, an amiable diſpoſition, and elegance of manners, and brought with her a little money, which, though it would be accounted nothing now, was ſomething in thoſe days to one in his ſituation in life. After giving to him a numerous family, and participating with him the changes of fortune which he experienced, ſhe peacefully departed this life in ſummer 1786.

In the year 1746, Cullen, who had now taken the degree of doctor in phyſic, was appointed a lecturer in chemiſtry in the Univerſity of Glaſgow: and in the month of October began his lectures in that ſcience. His ſingular talents for arrangement, his diſtinctneſs of enunciation, his vivacity of manner, and his knowledge of the ſcience he taught, rendered his lectures intereſting to the ſtudents to a degree that had been till then unknown at that univerſity. He became, therefore, in ſome meaſure, adored by the ſtudents. The former profeſſors were eclipſed by the brilliancy of his reputation; and he had to experience all thoſe little rubs that envy and diſappointed ambition naturally threw in his way. Regardleſs, however, of theſe ſecret chagreens, he preſſed forward with ardour in his literary career; and, ſupported by the favour of the public, he conſoled himſelf for the contumely he met with from a few individuals. His practice as a phyſician increaſed from day to day; and a vacancy having occurred in the year 1751, he was then appointed by the king profeſſor of medicine in that univerſity. This new appointment ſerved only to call forth his powers, and to bring to light talents that it was not formerly known he poſſeſſed; ſo that his fame continued to increaſe.

As, at that period, the patrons of the univerſity of Edinburgh were conſtantly on the watch for the moſt eminent medical men to ſupport the riſing fame of the college, their attention was ſoon directed towards Cullen; who on the death of Dr Plumber, profeſſor of chemiſtry, was, in 1756 unanimouſly invited to accept the vacant chair. This invitation he accepted: and having reſigned all his employments in Glaſgow, he began his academical career in Edinburgh in the month of October of that year, and there he reſided till his death.

If the admiſſion of Cullen into the univerſity of Glaſgow gave great ſpirit to the exertions of the ſtudents, this was ſtill, if poſſible, more ſtrongly felt in Edinburgh. Chemiſtry, which had been till that time of ſmall account in that univerſity, and was attended to by very few of the ſtudents, inſtantly became a favourite ſtudy; and the lectures upon that ſcience were more frequented than any others in the univerſity, anatomy alone excepted. The ſtudents, in general, ſpoke of Cullen with the rapturous ardour that is natural to youth when they are highly pleaſed. Theſe eulogiums appeared extravagant to moderate men, and could not fail to prove diſguſting to his colleagues. A party was formed among the ſtudents for oppoſing this new favourite of the public; and theſe ſtudents by miſrepreſenting the doctrines of Cullen to others who could not have an opportunity of hearing theſe doctrines themſelves, made even ſome of the moſt intelligent men in the univerſity think it their duty publicly to oppoſe theſe imaginary tenets. The ferment was thus augmented; and it was ſome time before the profeſſors diſcovered the arts by which they had been impoſed upon, and univerſal harmony reſtored.

During this time of public ferment Cullen went ſteadily forward, without taking any part himſelf in theſe diſputes. He never gave ear to any tales reſpecting his colleagues, nor took any notice of the doctrines they taught: That ſome of their unguarded ſtrictures might at times come to his knowledge, is not impoſſible; but if they did, they ſeemed to make no impreſſion on his mind.

Theſe attempts of a party of ſtudents to lower the character of Cullen on his firſt outſet in the univerſity of Edinburgh having proved fruitleſs, his fame as a profeſſor, and his reputation as a phyſician, became more and more reſpected every day. Nor could it well be otherwiſe: Cullen's profeſſional knowledge was always great, and his manner of lecturing ſingularly clear and intelligible, lively and entertaining; and to his patients, his conduct in general as a phyſician was ſo pleaſing, his addreſs ſo affable and engaging, and his manner ſo open, ſo kind, and ſo little regulated by pecuniary conſiderations, that it was impoſſible for thoſe who had occaſion to call once for his medical aſſiſtance, ever to be ſatisfied on any future occaſion without it. He became the friend and companion of every family he viſited; and his future acquaintance could not be diſpenſed with.

But if Dr Cullen in his public capacity deſerved to be *admired*, in his private capacity by his ſtudents he deſerved to be *adored*. His conduct to them was ſo attentive, and the intereſt he took in the private concerns of all thoſe ſtudents who applied to him for advice, was ſo cordial and ſo warm, that it was impoſſible for any one who had a heart ſuſceptible of generous emotions, not to be enraptured with a conduct ſo uncommon and ſo kind. Among ingenuous youth, gratitude eaſily degenerates into rapture—into reſpect nearly allied to adoration. Thoſe who advert to this natural conſtruction of the human mind, will be at no loſs to account for that popularity that Cullen enjoyed—a popularity, that thoſe who attempt to weigh every occurrence by the cool ſtandard of *reaſon* alone, will be inclined to think exceſſive. It is fortunate, however, that the bulk of mankind will ever be influenced in their judgment not leſs by feelings and affections than by the cold and phlegmatic dictates of *reaſon*. The adoration which generous conduct excites, is the reward which nature hath appropriated excluſively to diſintereſted beneficence. This was the ſecret charm that Cullen ever carried about with him, which faſcinated ſuch numbers of thoſe who had intimate acceſs to him.

This was the power, which his envious opponents never could have an opportunity of feeling.

The general conduct of Cullen to his ſtudents was thus. With all ſuch as he obſerved to be attentive and diligent, he formed an early acquaintance, by inviting them by twos, by threes, or by fours at a time, to ſup with him, converſing with them on theſe occaſions with the moſt engaging eaſe, and freely entering with them on the ſubjects of their ſtudies, their amuſements, their difficulties, their hopes, and future proſpects. In this way, he uſually invited the whole of his numerous claſs, till he made himſelf acquainted with their abilities, their private character, and their objects of purſuit. Thoſe among them whom he found moſt aſſiduous, beſt diſpoſed, or the moſt friendleſs, he invited the moſt frequently, till an intimacy was gradually formed, which proved highly beneficial to them. Their doubts, with regard to their objects of ſtudy, he liſtened to with attention, and ſolved with the moſt obliging condeſcenſion. His library, which conſiſted of an excellent aſſortment of the beſt books, eſpecially on medical ſubjects, was at all times open for their accommodation; and his advice in every caſe of difficulty to them they always had it in their power moſt readily to obtain. They ſeemed to be his family; and few perſons of diſtinguiſhed merit have left the univerſity of Edinburgh in his time with whom he did not keep up a correſpondence till they were fairly eſtabliſhed in buſineſs. By theſe means he came to have a moſt accurate knowledge of the ſtate of every country, with reſpect to practitioners in the medical line; the only uſe he made of which knowledge, was to direct the ſtudents in their choice of places where they might have an opportunity of engaging in buſineſs with a reaſonable proſpect of ſucceſs. Many, very many, able men has he thus put into a good line of buſineſs where they never could have thought of it themſelves, and they are now reaping the fruits of this beneficent foreſight on his part.

Nor was it in this way only that he befriended the ſtudents at the univerſity at Edinburgh. Poſſeſſing a benevolence of mind that made him ever think firſt of the wants of others, and recollecting the difficulties that he himſelf had had to ſtruggle with in his younger days, he was at all times ſingularly attentive to their pecuniary concerns. From his general acquaintance among the ſtudents, and the friendly habits he was on with many of them, he found no difficulty in diſcovering thoſe among them who were rather in hampered circumſtances, without being obliged to hurt their delicacy in any degree. To ſuch perſons, when their habits of ſtudy admitted of it, he was peculiarly attentive. They were more frequently invited to his houſe than others; they were treated with more than uſual kindneſs and familiarity; they were conducted to his library, and encouraged by the moſt delicate addreſs to borrow from it freely whatever books he thought they had occaſion for; and as perſons in theſe circumſtances were uſually more ſhy in this reſpect than others, books were ſometimes preſſed upon them as a ſort of conſtraint, by the Doctor inſiſting to have their opinion of ſuch or ſuch paſſages they had not read, and deſiring them to carry the book home for that purpoſe. He, in ſhort, behaved to them rather as if he courted their company, and ſtood in need of their acquaintance than they of his. He thus raiſed them in the opinion of their acquaintance to a much higher degree of eſtimation than they could otherwiſe have obtained; which, to people whoſe minds were depreſſed by penury, and whoſe ſenſe of honour was ſharpened by the conſciouſneſs of an inferiority of a certain kind, was ſingularly engaging. Thus they were inſpired with a ſecret ſenſe of dignity, which elevated their minds, and excited an uncommon ardour of purſuit, inſtead of that melancholy inactivity which is ſo natural in ſuch circumſtances, and which too often leads to deſpair. Nor was he leſs delicate in the manner of ſupplying their wants, than attentive to diſcover them. He often found out ſome polite excuſe for refuſing to take payment for a firſt courſe, and never was at a loſs for one to an after courſe. Before they could have an opportunity of applying for a ticket, he would ſometimes lead the converſation to ſome ſubject that occurred in the courſe of his lectures; and as his lectures were never put in writing by himſelf, he would ſometimes beg the favour to ſee their notes, if he knew they had been taken with attention, under a pretext of aſſiſting his memory. Sometimes he would expreſs a wiſh to have their opinion of a particular part of his courſe, and preſented them with a ticket for that purpoſe; and ſometimes he refuſed to take payment, under the pretext that they had not received his full courſe the preceding year, ſome part of it having been neceſſarily omitted for want of time, which he meant to include in this courſe. By ſuch delicate addreſs in which he greatly excelled, he took care to forerun their wants. Thus he not only gave them the benefit of his own lectures, but by refuſing to take their money, he alſo enabled them to attend thoſe of others that were neceſſary to complete their courſe of ſtudies. Theſe were particular devices he adopted to individuals to whom economy was neceſſary; but it was a general rule with him never to take money from any ſtudent for more than two courſes of the ſame ſet of lectures, permitting him to attend theſe lectures as many years longer as he pleaſed *gratis*.

He introduced another general rule into the univerſity, that was dictated by the ſame principle of diſintereſted beneficence, that ought not to be here paſſed over in ſilence. Before he came to Edinburgh, it was the cuſtom of medical profeſſors to accept of fees for their medical aſſiſtance when wanted, even from medical ſtudents themſelves, who were perhaps attending the profeſſor's own lectures at the time. But Cullen never would take fees as a phyſician from any ſtudent at the univerſity, though he attended them, when called in as a phyſician, with the ſame aſſiduity and care as if they had been perſons of the firſt rank, who paid him moſt liberally. This gradually induced others to adopt a ſimilar practice; ſo that it is now become a general rule for medical profeſſors to decline taking any fees when their aſſiſtance is neceſſary to a ſtudent. For this uſeful reform, with many others, the ſtudents of the univerſity of Edinburgh are ſolely indebted to the liberality of Dr Cullen.

The firſt lectures which Cullen delivered in Edinburgh were on chemiſtry; and for many years he alſo gave clinical lectures on the caſes which occurred in the royal infirmary. In the month of February, 1763, Dr Alſton died, after having begun his uſual courſe of lectures on the materia medica; and the magiſtrates of Edinburgh, as patrons of that profeſſorſhip in the univerſity,

verſity, appointed Dr Cullen to that chair, requeſting that he would finiſh the courſe of lectures that had been begun for that ſeaſon; this he agreed to do; and though he was under a neceſſity of going on with the courſe in a few days after he was nominated, he did not once think of reading the lectures of his predeceſſor, but reſolved to deliver a new courſe entirely his own. The popularity of Cullen at this time may be gueſſed at by the increaſe of new ſtudents who came to attend his courſe in addition to the eight or ten who had entered to Dr Alſton. The new ſtudents exceeded 100. An imperfect copy of theſe lectures thus fabricated in haſte, having been publiſhed, the Doctor thought it neceſſary to give a more correct edition of them in the latter part of his life. But his faculties being then much impaired, his friends looked in vain for thoſe ſtriking beauties that characterized his literary exertions in the prime of life.

Some years afterwards, on the death of Dr White, the magiſtrates once more appointed Dr Cullen to give lectures on the theory of phyſic in his ſtead. And it was on that occaſion Dr Cullen thought it expedient to reſign the chemical chair in favour of Dr Black, his former pupil, whoſe talents in that department of ſcience were then well known, and who has filled the chair ever ſince with great ſatisfaction to the public. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applauſe on the practice of phyſic, Dr John Gregory, (whoſe name can never be mentioned by any one who had the pleaſure of his acquaintance, without the warmeſt tribute of a grateful reſpect) having become a candidate for this place along with Dr Cullen, a ſort of compromiſe took place between them, by which they agreed each to give lectures alternately on the theory and on the practice of phyſic during their joint lives, the longeſt ſurvivor being allowed to hold either of the claſſes he ſhould incline. In conſequence of this agreement Dr Cullen delivered the *firſt* courſe of lectures on the practice of phyſic in winter 1766, and Dr Gregory ſucceeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the ſtudents than this. Both theſe men poſſeſſed great talents, though of a kind extremely diſſimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and reſpected the talents of the other. They co-operated, therefore, in the happieſt manner, to enlarge the underſtanding, and to forward the purſuits of their pupils. Unfortunately this arrangement was ſoon deſtroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a ſudden and unforeſeen event. After this time, Cullen continued to give lectures on the practice of phyſic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

In drawing the character of Dr Cullen, Dr Anderſon, to whom we are indebted for this ſketch, obſerves, that in ſcientific purſuits men may be arranged into two grand claſſes, which, though greatly different from each other in their extremes, yet approximate at times ſo near as to be blended indiſcriminately together; thoſe who poſſeſs a talent for detail, and thoſe who are endowed with the faculty of arrangement. The firſt may be ſaid to view objects individually as through a microſcope. The field of viſion is confined; but the objects included within that field, which muſt uſually be conſidered ſingly and apart from all others, are ſeen with a wondrous degree of accuracy and diſtinctneſs. The other takes a ſweeping view of the univerſe at large, conſiders every object he perceives, not individually, but as a part of one harmonious whole: His mind is therefore not ſo much employed in examining the ſeparate parts of this individual object, as in tracing its relations, connections, and dependencies, on thoſe around it.—Such was the turn of Cullen's mind. The talent for arrangement was that which peculiarly diſtinguiſhed him from the ordinary claſs of mortals; and this talent he poſſeſſed perhaps in a more diſtinguiſhed degree than any other perſon of the age in which he lived. Many perſons exceeded him in the minute knowledge of particular departments, who, knowing this naturally looked upon him as their inferior; but poſſeſſing not at the ſame time that glorious faculty, which, "with an eye wide roaming, glances from the earth to heaven," or the charms which this talent can infuſe into congenial minds, felt diſguſt at the pre-eminence he obtained, and aſtoniſhment at the means by which he obtained it. An Ariſtotle and a Bacon have had their talents in like manner appreciated; and many are the perſons who can neither be exalted to ſublime ideas with Homer, nor raviſhed with the natural touches of a Shakeſpeare. Such things are wiſely ordered, that every department in the univerſe may be properly filled by thoſe who have talents exactly ſuited to the taſk aſſigned them by heaven.

Had Cullen, however, poſſeſſed the talents for arrangement alone, ſmall would have been his title to that high degree of applauſe he has attained. Without a knowledge of *facts*, a talent for arrangement produces nothing but chimeras; without materials to work upon, the ſtructures which an over-heated imagination may rear up are merely "the baſeleſs fabric of a viſion." No man was more ſenſible of the juſtneſs of this remark than Dr Cullen, and few were at greater pains to avoid it. His whole life, indeed, was employed, almoſt without interruption, in collecting facts. Whether he was reading, or walking, or converſing, theſe were continually falling into his way. With the keen perception of an eagle, he marked them at the firſt glance; and without ſtopping at the time to examine them, they were ſtored up in his memory, to be drawn forth as occaſion required, to be confronted with other facts that had been obtained after the ſame manner, and to have their truth aſcertained, or their falſity proved, by the evidence which ſhould appear when carefully examined at the impartial bar of juſtice. Without a memory retentive in a ſingular degree, this could not have been done; but ſo very extraordinary was Dr Cullen's memory, that till towards the very decline of life, there was ſcarcely a fact that had ever occurred to him which he could not readily recollect, with all its concomitant circumſtances, whenever he had occaſion to refer to it. It was this faculty which ſo much abridged his labour in ſtudy, and enabled him ſo happily to avail himſelf of the labour of others in all his literary ſpeculations. He often reaped more by the converſation of an hour than another man would have done in whole weeks of laborious ſtudy.

In his prelections, Dr Cullen never attempted to read. His lectures were delivered *viva voce*, without having been previouſly put into writing, or thrown into any particular arrangement. The vigour of his mind was ſuch, that nothing more was neceſſary than a few ſhort notes before him, merely to prevent him from varying from the general order he had been accuſtomed to obſerve. This gave to his diſcourſes an eaſe, a vivacity, a variety, and a force, that are rarely to be met with in academical diſcourſes. His lectures, by conſequence, upon the ſame ſubject were never exactly the ſame. Their general tenor indeed was not much varied; but the particular illuſtrations were always new, well ſuited to the circumſtances that attracted the general attention of the day, and were delivered in the particular way that accorded with the caſt of mind the prelector found himſelf in at the time. To theſe circumſtances muſt be aſcribed that energetic artleſs elocution, which rendered his lectures ſo generally captivating to his hearers. Even thoſe who could not follow him in thoſe extenſive views his penetrating mind glanced at, or who were not able to underſtand thoſe apt alluſions to collateral objects which he could only rapidly point at as he went along, could not help being warmed in ſome meaſure by the vivacity of his manner. But to thoſe who could follow him in his rapid career, the ideas he ſuggeſted were ſo numerous, the views he laid open were ſo extenſive, and the objects to be attained were ſo important—that every active faculty of the mind was rouſed; and ſuch an ardour of enthuſiaſm was excited in the proſecution of ſtudy, as appeared to be perfectly inexplicable to thoſe who were merely unconcerned ſpectators. In conſequence of this unſhackled freedom in the compoſition and delivery of his lectures, every circumſtance was in the niceſt uniſon with the tone of voice and expreſſion of countenance, which the particular caſt of mind he was in at the time inſpired. Was he joyous, all the figures introduced for illuſtration were fitted to excite hilarity and good humour: was he grave, the objects brought under view were of a nature more ſolemn and grand: and was he peeviſh, there was a peculiarity of manner in thought, in word, and in action, which produced a moſt ſtriking and intereſting effect. The languor of a nerveleſs uniformity was never experienced, nor did an abortive attempt to excite emotions that the ſpeaker himſelf could not at the time feel, ever produce thoſe diſcordant ideas which prove diſguſting and unpleaſing.

It would ſeem as if Dr Cullen had conſidered the proper buſineſs of a preceptor to be that of putting his pupils into a proper train of ſtudy, ſo as to enable them to proſecute thoſe ſtudies at a future period, and to carry them on much farther than the ſhort time allowed for academical prelections would admit. He did not, therefore, ſo much ſtrive to make thoſe who attended his lectures deeply verſed in the particular details of objects, as to give them a general view of the whole ſubject; to ſhew what had been already attained reſpecting it; to point out what remained yet to be diſcovered; and to put them into a train of ſtudy that ſhould enable them, at a future period, to remove thoſe difficulties that had hitherto obſtructed our progreſs; and thus to advance of themſelves to farther and farther degrees of perfection. If theſe were his views, nothing could be more happily adapted to them than the mode he invariably purſued. He firſt drew, with the ſtriking touches of a maſter, a rapid and general outline of the ſubject, by which the whole figure was ſeen at once to ſtart boldly from the canvas, diſtinct in all its parts, and unmixed with any other object. He then began anew to retrace the picture, to touch up the leſſer parts, and to finiſh the whole in as perfect a manner as the ſtate of our knowledge at the time would permit. Where materials were wanting, the picture there continued to remain imperfect. The wants were thus rendered obvious; and the means of ſupplying theſe were pointed out with the moſt careful diſcrimination. The ſtudent, whenever he looked back to the ſubject, perceived the defects; and his hopes being awakened, he felt an irreſiſtible impulſe to explore that hitherto untrodden path which had been pointed out to him, and fill up the chaſm which ſtill remained. Thus were the active faculties of the mind moſt powerfully excited; and inſtead of labouring himſelf to ſupply deficiencies that far exceeded the power of any one man to accompliſh, he ſet thouſands at work to fulfil the taſk, and put them into a train of going on with it, when he himſelf ſhould be gone to that country "from whoſe dread bourne no traveller returns."

It was to theſe talents, and to this mode of applying them, that Dr Cullen owed his celebrity as a profeſſor; and it was in this manner that he has perhaps done more towards the advancement of ſcience than any other man of his time, though many individuals might perhaps be found who were more deeply verſed in the particular departments he taught than he himſelf was. Chemiſtry, which was before his time a moſt diſguſting purſuit, was by him rendered a ſtudy ſo pleaſing, ſo eaſy, and ſo attractive, that it is now proſecuted by numbers as an agreeable recreation, who but for the lights that were thrown upon it by Cullen and his pupils, would never have thought of engaging in it at all; though perhaps they never heard of Cullen's name, nor have at this time the moſt diſtant idea that they owe any obligations to him; and the ſame may be ſaid of the other branches of ſcience which he taught.

According to a man who knew him well, there are three things which eminently diſtinguiſhed Cullen as a profeſſor. "The energy of his mind, by which he viewed every ſubject with ardour, and combined it immediately with the whole of his knowledge.

"The ſcientific arrangement which he gave to his ſubject, by which there was a *lucidus ordo* to the dulleſt ſcholar. He was the firſt perſon in this country who made chemiſtry ceaſe to be a chaos.

"A wonderful art of intereſting the ſtudents in every thing which he taught, and of raiſing an emulative enthuſiaſm among them."

We are well aware that this character will by many be deemed an extravagant panegyric; but having no opportunity of judging for ourſelves, we would rather adopt from others an extravagant panegyric than an unmerited cenſure. Dr Anderſon himſelf admits that Cullen's character was far from perfect; and, in the opinion of moſt other men with whom we have converſed on the ſubject, and who were at the ſame time qualified to form an eſtimate of his mental powers, his imagination was not balanced by his judgment. Hence the common remark in the univerſity of Edinburgh, that Dr Cullen was more ſucceſsful in demoliſhing the theories of others than in giving ſtability to thoſe which were reared by himſelf.

Dr Cullen's external appearance, though ſtriking and not diſtrict; and between the two firſt named diſtricts and the ſtate of Kentucky. The ridge is about 30 miles broad, and extends from Crow creek, on Tenneſſee river from S. W. to N. E. The place where the Tenneſſee breaks through the Great ridge, called the *Whirl* or *Suck*, is 250 miles above the Muſcle ſhoals. Limeſtone is found on both ſides the mountain. The mountain conſiſts of the moſt ſtupendous piles of craggy rocks of any mountain in the weſtern country. In ſeveral parts of it, it is inacceſſible for miles, even to the Indians on foot. In one place particularly, near the ſummit of the mountain, there is a moſt remarkable ledge of rocks of about 30 miles in length, and 200 feet thick, ſhewing a perpendicular face to the S. E. more noble and grand than any artificial fortification in the known world, and apparently equal in point of regularity.—*ib.*

Cumberland *River*, called by the Indians "Shawanee," and by the French "Shavanon," falls into the Ohio 10 miles above the mouth of Tenneſſee river, and about 24 miles due E. from fort Maſſac, and 1113 below Pittſburg. It is navigable for large veſſels to Naſhville in Tenneſſee, and from thence to the mouth of Obed's or Obas river. The Caney fork, Harpeth, Stones, Red, and Obed's, are its chief branches; ſome of them are navigable to a great diſtance.

The Cumberland mountains in Virginia ſeparate the head waters of this river from thoſe of Clinch river. It runs S. W. till it comes near the S. line of Kentucky, when its courſe is weſterly, in general, through Lincoln co. receiving many ſtreams from each ſide; thence it flows S. W. into the ſtate of Tenneſſee, where it takes a winding courſe, incloſing Sumner, Davidſon, and Tenneſſee counties; afterwards it takes a N. weſtern direction and re-enters the ſtate of Kentucky; and from thence it preſerves nearly an uniform diſtance from Tenneſſee river to its mouth, where it is 300 yards wide. It is 200 yards broad at Naſhville, and its whole length is computed to be above 450 miles.—*ib.*

Cumberland-River, a place ſo called, where a poſt office is kept, in Tenneſſee, 13 miles from Cumberland mountain, and 80 from the Crab-Orchard in Kentucky.—*ib.*

CUMMASHAWAS, or *Cummaſhawaa*, a ſound and village on the E. ſide of Waſhington iſland, on the N. W. coaſt of N. America. The port is capacious and ſafe, and its mouth lies in 53. 2. 30. N. lat. and in 228. 22. W. long. In this port Capt. Ingraham remained ſome time; and he obſerves, in his journal, that here, in direct oppoſition to moſt other parts of the world, the women maintained a precedency to the men in every point; inſomuch that a man dares not trade without the concurrence of his wife; and that he has often been witneſs to men's being abuſed for parting with ſkins before their approbation was obtained: and this precedency often occaſioned much diſturbance.—*ib.*

CUMMINGTON, a townſhip in Hampſhire co. Maſſachuſetts, having 873 inhabitants; lying about 20 miles N. W. of Northampton, and 120 N. W. by W. of Boſton. It was incorporated in 1779.—*ib.*

CURFEU-Bell (ſee Curfew, *Encycl.*), called in the law Latin of the middle ages *ignitegium* or *pyritegium*, and in French, *cuvre-feu*—was a ſignal for all perſons to extinguiſh their fires at a certain hour. In thoſe ages people made fires in their houſes in a hole or pit in the centre of the floor, under an opening formed in the roof; and when the fire was burnt out, or the family went to bed, the hole was ſhut by a cover of wood or of earth. This practice ſtill prevails among the cottagers in ſome parts of Scotland, and we doubt not of other countries. In the dark ages, when all ranks of people were turbulent, a law was almoſt everywhere eſtabliſhed, that the fire ſhould be extinguiſhed at a certain time in the evening; that the cover ſhould be put over the fire-place; and that all the family ſhould retire to reſt, or at leaſt keep within doors. The time when this ought to be done was ſignified by the ringing of a bell, called therefore the *curfeu-bell* or *ignitegium*. The law of William the Conqueror, which introduced this practice into England, as has been mentioned in the Encyclopædia, was aboliſhed by Henry I. in 1100.

The ringing of the curfeu-bell gave riſe to the prayer bell, as it is called, which is ſtill retained in ſome Proteſtant countries. Pope John XXIII. with a view to avert certain apprehended misfortunes, which rendered his life uncomfortable, gave orders, that every perſon, on hearing the *ignitegium* ſhould repeat the *Ave Maria* three times. When the appearance of a comet, and a dread of the Turks, afterwards alarmed all Chriſtendom, Pope Calixtus III. increaſed theſe periodical times of prayer, by ordering the prayer-bell to be rung alſo at noon. *Beckmann's Hiſtory of Inventions.*

CURRITUCK *Co.* is ſituated on the ſea coaſt of Edenton diſtrict, N. Carolina, and forms the N. E. corner of the ſtate; being bounded E. by Currituck ſound, N. by the ſtate of Virginia, S. by Albemarle ſound, and W. by Camden co.; containing 5219 inhabitants, of whom 1103 are ſlaves. Diſmal ſwamp lies in this county, on the S. ſide of Albemarle ſound, and is now ſuppoſed to contain one of the moſt valuable rice eſtates in America. In the midſt of this Diſmal, which contains upwards of 350,000 acres, is a lake of about 11 miles long and 7 miles broad. A navigable canal, 20 feet wide and 5½ miles long, connects the waters of the lake with the head of Skuppernong river. About 500 yards from the lake, the proprietors have erected ſeveral ſaw mills: and as the water of the lake is higher than the banks of the canal, the company can at any time lay under water about 10,000 acres of rich ſwamp, which proves admirably fitted for rice.—*Morſe.*

Currituck, or *Caratunk*, a townſhip in the diſtrict of Maine, 28 miles above Norridgewalk. In 1792 this was the uppermoſt ſettlement on Kennebeck river, and then conſiſted of about 20 families.—*ib.*

CURVE of Equable Approach. It was firſt propoſed by Leibnitz, namely, to find a curve, down which a body deſcending by the force of gravity ſhall make equal approaches to the horizon in equal portions of time. It has been found by Bernoulli and others, that the curve is the ſecond cubical parabola, placed with its vertex uppermoſt, and which the deſcending body muſt enter with a certain determinate velocity. Varignon rendered the queſtion general for any law of gravity, by which a body may approach towards a given point by equal ſpaces in equal times. And Maupertuis alſo reſolved the problem in the caſe of a body

D.

DAGELET, the name given by *La Perouſe*, the celebrated though unfortunate navigator, to an iſland on the coaſt of Corea (See Corea *Encycl.*) which he diſcovered in the year 1787. It is little more than three leagues in circumference; and our author almoſt made its circuit at the diſtance of a mile without finding bottom. This ſmall ſpot is very ſteep, but covered with the fineſt trees from the ſea-ſhore to the ſummit. A rampart of bare rock, like a wall, encircles the whole outline of it, with the exception of ſeven little ſandy creeks where it is poſſible to land. In theſe creeks the Frenchmen ſaw upon the ſtocks ſome boats of a conſtruction altogether Chineſe; but the ſight of their ſhips frightened the workmen, who fled from their dock-yard into the wood, which was not more than fifty paces diſtant. As a few huts were ſeen, but neither villages nor cultivation, La Perouſe concluded that the iſland is without inhabitants, and that the men whom he ſaw at work were Corean carpenters, who during the ſummer months go with proviſion to Dagelet for the purpoſe of building boats, which they ſell upon the continent. He places the north eaſt point of this iſland in N. Lat. 37°. 25′. and E. Long. 129°. 2′. from Paris.

DAGSBOROUGH, a poſt town in Suſſex co. Delaware, ſituated on the N. W. bank of Peper's creek, a branch of Indian river, and contains about 40 houſes. It is 19 miles from Broad hill, or Clowes', and 127 S. from Philadelphia.—*Morse.*

DAIRY is a word which ſignifies ſometimes the art of making various kinds of food from milk; ſometimes the place where milk is manufactured; and ſometimes the management of a milk-farm. On the *dairy*, in the firſt and ſecond of theſe ſenſes, enough has been ſaid in the *Encyclopædia* under the titles Butter, Cheese, and Dairy; on the management of a milk-farm that work contains nothing.

When a dairy is eſtabliſhed, the undertaker may ſometimes think it his intereſt to obtain the greateſt poſſible quantity of produce; ſometimes it may be more beneficial for him to have it of the fineſt quality; and at other times it may be neceſſary to have both theſe objects in view, the one or the other in a greater or leſs proportion; it is therefore of importance that he ſhould know how he may accompliſh the one or the other of theſe purpoſes in the eaſieſt and moſt direct manner.

To be able to convert his milk to the higheſt poſſible profit in every caſe, he ought to be fully acquainted with every circumſtance reſpecting the manufacture both of butter and of cheeſe: as it may in ſome caſes happen, that a certain portion of that milk may be more advantageouſly converted into butter than into cheeſe, while another portion of it would return more profit if made into cheeſe.

The firſt thing to be adverted to in an undertaking of this nature is to chooſe cows of a proper ſort. Among this claſs of animals, it is found by experience, that ſome kinds give milk of a much thicker conſiſtence, and richer quality, than others; nor is this richneſs of quality neceſſarily connected with the ſmallneſs of the quantity yielded by cows of nearly an equal ſize; it therefore behoves the owner of a dairy to be peculiarly attentive to this circumſtance. In judging of the value of a cow, it ought rather to be the quantity and the quality of the cream produced from the milk of the cow, in a given time, than the quantity of the milk itſelf: this is a circumſtance that will be ſhewn hereafter to be of more importance than is generally imagined. The ſmall cows of the Alderney breed afford the richeſt milk hitherto known; but individual cows in every country may be found, by a careful ſelection, that afford much thicker milk than others; theſe therefore ought to be ſearched for with care, and their breed reared with attention as being peculiarly valuable.

Few perſons, who have had any experience at all in the dairy, can be ignorant, however, that in comparing the milk of two cows, to judge of their reſpective qualities, particular attention muſt be paid to the time that has elapſed ſince their calving; for the milk of the ſame cow is always thinner ſoon after calving than it is afterwards; as it gradually becomes thicker, though generally leſs in quantity in proportion to the time ſince the cow has calved. The colour of the milk ſoon after calving is richer than it is afterwards; but this, eſpecially for the firſt two weeks, is a faulty colour, that ought not to be coveted.

To make the cows give abundance of milk, and of a good quality, they muſt at all times have plenty of food. Graſs is the beſt food yet known for this purpoſe, and that kind of graſs which ſprings up ſpontaneouſly on rich dry ſoils is the beſt of all. If the temperature of the climate be ſuch as to permit the cows to graze at eaſe throughout the day, they ſhould be ſuffered to range on ſuch paſtures at freedom: but if the cows are ſo much incommoded by the heat as to be prevented from eating through the day, they ought in that caſe to be taken into cool ſhades for protection; where, after allowing them a proper time to ruminate, they ſhould be ſupplied with abundance of green food freſh cut for the purpoſe, and given to them by hand frequently, in ſmall quantities freſh and freſh, ſo as to induce them to eat it with pleaſure. When the heat of the day is over, and they can remain abroad with eaſe, they may be again turned into the paſture, where they ſhould be allowed to range with freedom all night, during the mild weather of ſummer.

Cows, if abundantly fed, ſhould be milked three times a-day during the whole of the ſummer ſeaſon (a); in the morning early, at noon, and in the evening, juſt before night-fall. In the choice of perſons for milking the cows, great caution ſhould be employed; for if that operation be not carefully and properly performed, not only the quantity of the produce of the dairy will be greatly diminiſhed, but its quality alſo will be very much debaſed; for if all the milk be not thoroughly drawn from a cow when ſhe is milked, that portion of milk which is left in the udder ſeems to be gradually abſorbed into the ſyſtem, and Nature generates no more than to ſupply the waſte of what has been taken away. If this leſſened quantity be not again thoroughly drawn off, it occaſions a yet farther diminution of the quantity of milk generated; and thus it may be made to proceed in perpetual progreſſion from little to leſs, till none at all is produced. In ſhort, this is the practice in all caſes followed, when it is meant to allow a cow's milk to dry up entirely, without doing her hurt. In this manner, therefore, the profits of a dairy might be wonderfully diminiſhed; ſo that it much behoves the owner of it to be extremely attentive to this circumſtance, if he wiſhes to avoid ruin. It ought to be a rule without an exception, never to allow this important department to be entruſted, without controul, to the management of hired ſervants (B). Its importance will be ſtill more manifeſt from what follows.

(a) If cows be milked only twice in the day (24 hours), while they have abundance of ſucculent food, they will yield a much ſmaller quantity of milk, in the ſame time, than if they be milked three times. Some attentive

It is to Dr James Anderſon that we are indebted for theſe judicious obſervations, as well as for the following aphoriſms which though they may be in part known to attentive houſewives, he has reaſon to believe are not commonly adverted to as their importance deſerves.

horiſm 1. "Of the milk that is drawn from any cow at one time, that which comes off at the firſt is always thinner, and of a much worſe quality, than that which comes afterwards; and the richneſs goes on continually increaſing to the very laſt drop that can be drawn from the udder at that time."

Few perſons are ignorant that the milk which is laſt of all taken from the cow at milking (in this country called *ſtroakings*) is richer than the reſt of the milk; but fewer ſtill are aware of the greatneſs of the diſproportion between the quality of the firſt and the laſt drawn milk, from the ſame cow, at one milking. The following facts (ſays our author) reſpecting this circumſtance were aſcertained by me many years ago, and have been confirmed by many ſubſequent experiments and obſervations.

Having taken ſeveral large tea-cups, exactly of the ſame ſize and ſhape, one of theſe tea-cups was filled at the beginning of the milking, and the others at regular intervals, till the laſt, which was filled with the dregs of the ſtroakings. Theſe cups were then weighed, the weight of each having been ſettled, ſo as to aſcertain that the quantity of milk in each was preciſely the ſame; and from a great number of experiments, frequently repeated with many different cows; the reſult was in all caſes as follows:

The quantity of cream obtained from the firſt drawn cup was, in every caſe, much ſmaller than from that which was laſt drawn; and thoſe between afforded leſs or more as they were nearer the beginning or the end. It is unneceſſary here to ſpecify theſe intermediate proportions; but it is proper the reader ſhould be informed, that the quantity of cream obtained from the laſt-drawn cup, from ſome cows, exceeded that from the firſt in the proportion of ſixteen to one. In other cows, however, and in particular circumſtances, the diſproportion was not quite ſo great; but in no caſe did it fall ſhort of the rate of eight to one. Probably, upon an average of a great many cows, it might be found to run as ten or twelve to one.

Secondly, The difference in the quality of the cream, however, obtained from theſe two cups, was much greater than the difference in the quantity. In the firſt cup, the cream was a thin tough film, thinner, and perhaps whiter, than writing paper; in the laſt, the cream was of a thick *butyrous* conſiſtence, and of a glowing richneſs of colour that no other kind of cream is ever found to poſſeſs.

Thirdly, The difference in the quality of the milk that remained, after the cream was ſeparated, was perhaps ſtill greater than either in reſpect to the quantity or the quality of the cream. The milk in the firſt cup was a thin bluiſh liquid, as if a very large proportion of water had been mixed with ordinary milk; that in the laſt cup was of a thick conſiſtence, and yellow colour, more reſembling cream than milk both in taſte and appearance.

From this important experiment, it appears that the perſon who, by bad milking of his cows, loſes but half a pint of his milk, loſes in fact about as much cream as would be afforded by ſix or eight pints at the beginning, and loſes, beſides, that part of the cream which alone can give richneſs and high flavour to his butter.

Aphoriſm 2. "If milk be put into a diſh, and allowed to ſtand till it throws up cream, that portion of cream which riſes firſt to the ſurface is richer in quality, and greater in quantity, than what riſes in a ſecond equal ſpace of time; and the cream that riſes in the ſecond interval of time is greater in quantity, and richer in quality, than that which riſes in a third equal ſpace of time; that of the third than the fourth, and ſo on; the cream that riſes decreaſing in quantity, and declining in quality, continually, as long as any riſes to the ſurface."

Our

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tive obſervers think a cow, in theſe circumſtances, will give nearly as much milk at each time, if milked three times, as if ſhe were milked only twice. This fact, however, has not, that we know of, been aſcertained by experiment. There can be no doubt but they give more, how much more is not aſcertained; nor, whether it would be advantageous, in any caſe, to milk them four times, or oftener; nor, what effect frequent milking produces on the quality of the milk.

(B) Cows ſhould always be treated with great gentleneſs, and ſoothed by mild uſage, eſpecially when young and tickliſh, or when the paps are tender; in which laſt caſe the udder ought to be fomented with warm water before milking, and touched with the greateſt gentleneſs, otherwiſe the cow will be in danger of contracting bad habits, becoming ſtubborn and unruly, and retaining her milk ever after. A cow never lets down her milk pleaſantly to the perſon ſhe dreads or diſlikes. The udder and paps ſhould always be waſhed with clean water before milking; but care ſhould be taken that none of that water be admitted into the milking-pail.

Our ingenious author confeſſes, that his experiments not having been made with ſo much accuracy in this caſe as in the former, he was not enabled to aſcertain the difference in the proportion that takes place in equal portions of time; but they have been ſo often repeated as not to leave any room to doubt the fact, and it will be allowed to be a fact of no ſmall importance in the management of the dairy. It is not certain, however, but that a greater quantity of cream may, upon the whole, be obtained from the milk by taking it away at different times; but the proceſs is ſo troubleſome as not to be counterbalanced by the increaſed quantity obtained, if indeed an increaſed quantity be thus obtained, which is not as yet quite certain.

Aphoriſm 3. "Thick milk always throws up a ſmaller proportion of the cream it actually contains, to the ſurface, than milk that is thinner; but that cream is of a richer quality. If water be added to that thick milk, it will afford a conſiderably greater quantity of cream than it would have done if allowed to remain pure, but its quality is, at the ſame time, greatly debaſed."

This is a fact that every perſon attentive to a dairy muſt have remarked; but I have never (ſays our author) heard of any experiment that could aſcertain, either the preciſe amount of the increaſed quantity of cream that might thus be obtained, or of the ratio in the decreaſe of its quality. The effects of mixing water with the milk in a dairy are at leaſt aſcertained; and the knowledge of this fact will enable attentive perſons to follow that practice which they think will beſt promote their own intereſt.

Aphoriſm 4. "Milk which is put into a bucket or other proper veſſel, and carried in it to any conſiderable diſtance, ſo as to be much agitated, and in part cooled, before it be put into the milk-pans to ſettle for cream, never throws up ſo much, nor ſo rich cream, as if the ſame milk had been put into the milk-pans directly after it was milked."

In this caſe, it is believed the loſs of cream will be nearly in proportion to the time that has elapſed, and the agitation the milk has ſuſtained, after being drawn from the cow. But Dr Anderſon ſays that he is not yet in poſſeſſion of any experiments which ſufficiently aſcertain how much is to be aſcribed to the time, and the agitation, taken ſeparately. On every branch of agriculture we find experiments wanting, at each ſtep we advance in our enquiries; and it is the duty of every enquirer to point out, as he goes along where they are wanted, ſince the labours of no one man can poſſibly complete the whole.

From the above facts, the following corollaries ſeem to be clearly deducible:

Firſt. It is of importance that the cows ſhould be always milked as near the dairy as poſſible, to prevent the neceſſity of carrying and cooling the milk before it is put into the diſhes; and as cows are much hurt by far driving, it muſt be a great advantage in a dairy-farm to have the principal graſs fields as near the dairy or homeſtead as poſſible.

Secondly. The practice of putting the milk of all the cows of a large dairy into one veſſel, as it is milked, there to remain till the whole milking is finiſhed, before any part of it is put into the milk-pans—ſeems to be highly injudicious; not only on account of the loſs that is ſuſtained by agitation and cooling, but alſo, more eſpecially, becauſe it prevents the owner of the dairy from diſtinguiſhing the good from the bad cow's milk, ſo as to ſeparate theſe from each other, where it is neceſſary. He may thus have the whole of his dairy product greatly debaſed by the milk of one bad cow, for years together, without being able to diſcover it. A better practice, therefore, would be, to have the milk drawn from each cow put ſeparately into the creaming-pans as ſoon as it is milked, without being ever mixed with any other. Thus would the careful manager of the dairy be able on all occaſions to obſerve the particular quality of each individual cow's milk, as well as its quantity, and to know with preciſion which of his cows it was his intereſt to diſpoſe of and which of them he ought to keep and breed from.

Thirdly. If it be intended to make butter of a very fine quality, it will be adviſable in all caſes to keep the milk that is firſt drawn ſeparate from that which comes laſt; as it is obvious, that if this be not done, the quality of the butter will be greatly debaſed, without much augmenting its quantity. It is alſo obvious, that if this is done, the quality of the butter will be improved in proportion to the ſmallneſs of the quantity of the laſt-drawn milk that is retained; ſo that thoſe who wiſh to be ſingularly nice in this reſpect, will do well to retain only a very ſmall portion of the laſt-drawn milk.

To thoſe owners of dairies who have profit only in view, it muſt ever be a matter of trial and calculation, how far it is expedient for them to carry the improving of the quality of their butter at the expence of diminiſhing its quantity. In different ſituations prudence will point out different kinds of practice as moſt eligible; and all perſons muſt be left, after making accurate trials, to determine for themſelves. It is likewiſe a conſideration of no ſmall importance, to determine in what way the inferior milk, that is thus to be ſet apart where fine butter is wanted, can be employed with the greateſt profit. In the Highlands of Scotland they have adopted, without thinking of the improvement of their butter, a very ſimple and economical practice in this reſpect. As the rearing of calves is there a principal object with the farmer, every cow is allowed to ſuckle her own calf with a part of her milk, the remainder only being employed in the dairy. To give the calf its portion regularly, it is ſeparated from the cow, and kept in an incloſure, with all the other calves belonging to the ſame farm. At regular times, the cows are driven to the door of the incloſure, where the young calves fail not to meet them. Each calf is then ſeparately let out, and runs directly to its mother, where it ſucks till the dairy-maid judges it has had enough; ſhe then orders it to be driven away, having previouſly ſhackled the hinder legs of the mother, by a very ſimple contrivance, to oblige her to ſtand ſtill. Boys drive away the calf with ſwitches, and return it to the incloſure, while the dairy-maid milks off what was left by the calf; thus they proceed till the whole of the cows are milked. They obtain only a ſmall quantity of milk, it is true, but that milk is of an exceeding rich quality; which, in the hands of ſuch of the inhabitants as know how to manage it, is manufactured into the richeſt marrowy butter that can be anywhere met with. This richneſs of the Highland butter is univerſally aſcribed to the old graſs the cows feed upon in their remote glens; but it is in fact chiefly to be attributed to the practice here deſcribed, which has long prevailed in thoſe regions. Whether a ſimilar practice could be economically adopted elſewhere, our author takes not upon him to ſay; but doubtleſs other ſecondary uſes might be found for the milk of inferior quality. On ſome occaſions, it might be converted into butter of an inferior quality; on other occaſions, it might be ſold ſweet, where the ſituation of the farm was within reach of a market-town; and on others, it might be converted into cheeſes, which, by being made of ſweet milk, would be of a very fine quality if carefully made (c). Still other uſes might be deviſed for its application; of which the following is worthy of notice. Take common ſkimmed milk, when it has begun to turn ſour, put it into an upright ſtand churn, or a barrel with one of its ends out, or any other convenient veſſel. Heat ſome water, and pour it into a tub that is large enough to contain with eaſe the veſſel in which the milk was put. Set the veſſel containing the milk into the hot water, and let it remain there for the ſpace of one night. In the morning it will be found that the milk has ſeparated into two parts; a thick cream-like ſubſtance, which occupies the upper part of the veſſel, and a thin watery part, that remains at the bottom. Draw off the thin part, (called in Scotland *wigg*) by opening a ſtop-cock, placed for that purpoſe cloſe above the bottom, and reſerve the cream for uſe. Not much leſs than half of the milk is thus converted into a ſort of cream, which, when well made, ſeems to be as rich and fat as real cream itſelf, and is only diſtinguiſhable from it by its ſourneſs. It is eaten with ſugar, and eſteemed a great delicacy, and uſually ſells at double the price of freſh unſkimmed milk. It requires practice, however, to be able to make this nicely. The degree of the heat of the water, and many other circumſtances, greatly affecting the operation.

Fourthly. If the quality of the butter be the chief object attended to, it will be neceſſary, not only to ſeparate the firſt from the laſt drawn milk, but alſo to take nothing but the cream that is firſt ſeparated from the beſt milk, as it is this firſt riſing cream alone that is of the prime quality. The remainder of the milk, which will be ſtill ſweet, may be either employed for the purpoſe of making ſweet milk cheeſes, or may be allowed to ſtand, to throw up cream for making butter of an inferior quality, as circumſtances may direct.

Fifthly. From the above facts, we are enabled to perceive, that butter of the very beſt poſſible quality can only be obtained from a dairy of conſiderable extent, judiciouſly managed; for when only a ſmall portion of each cow's milk can be ſet apart for throwing up cream, and when only a ſmall proportion of that cream can be reſerved, of the prime quality, it follows (the quantity of milk being upon the whole very inconſiderable), that the quantity of prime cream produced would be ſo ſmall as to be ſcarcely worth manufacturing ſeparately.

Sixthly. From theſe premiſes we are alſo led to draw another concluſion, extremely different from the opinion that is commonly entertained on this ſubject, viz. That it ſeems probable, that the very beſt butter could be made with economy in thoſe dairies only where the manufacture of cheeſe is the principal object. The reaſons are obvious: If only a ſmall portion of milk ſhould be ſet apart for butter, all the reſt may be made into cheeſe, while it is yet warm from the cow, and perfectly ſweet; and if only that portion of cream which riſes during the firſt three or four hours after milking is to be reſerved for butter, the rich milk, which is left after that cream is ſeparated being ſtill perfectly ſweet, may be converted into cheeſe with as great advantage nearly as the newly milked milk itſelf.

But as it is not probable that many perſons could be found who would be willing to purchaſe the very fineſt butter, made in the manner above pointed out, at a price that would be ſufficient to indemnify the farmer for his trouble in making it, theſe hints are thrown out merely to ſhew the curious in what way butter poſſeſſing this ſuperior degree of excellence may be obtained, if they chooſe to be at the expence; but for an ordinary market, Dr Anderſon is ſatisfied, from experience and attentive obſervation, that if in general about the firſt drawn half of the milk be ſeparated at each milk-

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(c) The making of cheeſe has never yet been reduced to ſcientific principles, and conſequently the reaſoning relating to it is very inconcluſive. It is in general ſuppoſed, that the goodneſs of cheeſe depends almoſt entirely upon its richneſs, by which is meant the proportion of oily matter, whether natural or extraneous, it contains; nothing, however, is more certain, than that this opinion is erroneous. Sometimes a very lean cheeſe is much better taſted than one that is much fatter; and, which will appear to moſt perſons ſtill more extraordinary, it frequently happens, that a cheeſe that taſtes ſoft and fat, is much leaner than one that is hard, dry, and ſticky. The mode of manufacturing it occaſions this, and not the quantity of cream it contains. It is very poſſible by art to make poor ſkim milk cheeſe aſſume the ſoft buttery taſte and appearance even of cream cheeſe. This ſubject, therefore, deſerves to be more particularly elucidated than it has hitherto been.

Connected as they are with the object diſcuſſed in the text, we beg leave with our author to ſuggeſt the following particulars as proper objects of examination and experiment, viz. Is the quantity of caſeous matter afforded by milk neceſſarily connected with the proportion of cream that milk contains, or does it depend upon ſome other principle not hitherto inveſtigated? Without pretending to decide this queſtion, Dr Anderſon feels himſelf ſtrongly inclined to believe it does not depend upon the quantity of cream. It is well known that cow's milk, which always throws up more cream, and that of a much richer quality, than ewe-milk, does in no caſe afford above one half the proportion of cheeſe that ewe-milk does. Nor can this ſingular tendency of ewe-milk, to yield a great proportion of curd, be attributed to its ſuperior thickneſs; for cow-milk can be often had that is thicker and richer than ewe-milk, but it always affords a much ſmaller proportion of curd. From theſe conſiderations, it is not impoſſible but it might be found, upon a careful inveſtigation, that the refuſe milk, which ought to be ſeparated from the other in making the beſt butter, might be equally proper, or very nearly ſo, for making cheeſe as if no ſuch ſeparation had been made. We therefore recommend this as a proper object of experimental enquiry.

ing, and the remainder only ſet up for producing cream, and if that milk be allowed to ſtand to throw up the whole of its cream (even till it begins ſenſibly to taſte ſouriſh), and that cream be afterwards carefully managed, the butter thus obtained will be of a quality greatly ſuperior to what can uſually be procured at market, and its quantity not conſiderably leſs, than if the whole of the milk had been treated alike. This, therefore, is the practice that our author thinks moſt likely to ſuit the frugal farmer, as his butter, though of a ſuperior quality, could be afforded at a price that would always enſure it a rapid ſale.

Dr Anderſon throws out many other ingenious and uſeful obſervations on this important branch of rural economy. In particular, he points out, in the plaineſt manner, the requiſites of a good milk-houſe, which, as he truly obſerves, ſhould be cool in ſummer and warm in winter, ſo as to preſerve a temperature nearly the ſame throughout the year. But we have treated of this part of the ſubject elſewhere, and muſt therefore refer ſuch as are deſirous to know the doctor's ſentiments on it, to *the Letters and Papers of the Bath and Weſt of England Society* for the encouragement of agriculture, &c. or to the eighth volume of *the Repertory of Arts and Manufactures.*

DAHALAC, the largeſt iſland in the Red Sea, is thus deſcribed by Mr Bruce. It is low and even, the ſoil fixed gravel and white ſand, mixed with ſhells and other marine productions. It is deſtitute of all ſorts of herbage, at leaſt in ſummer, unleſs a ſmall quantity of bent graſs, juſt ſufficient to feed the few antelopes and goats that are on the iſland. There is a very beautiful ſpecies of this laſt animal found here, ſmall, ſhort-haired, with thin black ſharp horns, having rings upon them, and they are very ſwift of foot.

This iſland is, in many places, covered with large plantations of acacia trees, which grow to no height, ſeldom above eight feet, but ſpread wide, and turn flat at top, probably by the influence of the wind from the ſea. Though in the neighbourhood of Abyſſinia, Dahalac does not partake of its ſeaſons, no rain falls here from the end of March to the beginning of October; but in the intermediate months, eſpecially December, January and February, there are violent ſhowers for 12 hours at a time, which deluge the iſland, and fill the ciſterns ſo as to ſerve all next ſummer, for there are no hills nor mountains in Dahalac, and conſequently no ſprings. Theſe ciſterns alone preſerve the water, and of them there yet remain 370, all hewn out of the ſolid rock. They ſay theſe were the works of the Perſians; it is more probable they were thoſe of the firſt Ptolemies. But whoever were the conſtructors of theſe magnificent reſervoirs, they were a very different people from thoſe that now poſſeſs them, who have not induſtry enough to keep one of the 370 clear for the uſe of man. All of them are open to every ſort of animal, and half full of the filth they leave there, after drinking and waſhing in them; yet one of theſe ciſterns, cleaned and ſhut up with a door might afford them wholeſome ſweet water all the year over.

After the rains fall, a prodigious quantity of graſs immediately ſprings up; and the goats give the inhabitants milk, which in winter is the principal part of their ſubſiſtence; for they neither plow nor ſow; all their employment is to work the veſſels which trade to the different parts of the coaſt. One half of the inhabitants is conſtantly on the Arabian ſide, and by their labour is enabled to furniſh with *dora* (millet or Indian corn) and other proviſions the other half who ſtay at home; and when their time is expired, they are relieved by the other half, and ſupplied with neceſſaries in their turn. But the ſuſtenance of the poorer ſort is entirely ſhell and other fiſh. Their wives and daughters are very bold and expert fiſher-women. Several of them, entirely naked, ſwam off to the veſſel before it came to an anchor, begging handfuls of wheat, rice, or dora. They are very importunate and ſturdy beggars, and not eaſily put off with denials. Theſe miſerable people, who live in the villages not frequented by barks from Arabia, are ſometimes a whole year without taſting bread. Yet ſuch is the attachment to their place of nativity, they prefer living in this bare, barren, parched ſpot, almoſt in want of neceſſaries of every kind, eſpecially of theſe eſſential ones, bread and water, to thoſe pleaſant and plentiful countries on both ſides of them.

There are in Dahalac twelve villages or towns, of which each has a plantation of doomtrees round it, which furniſh the only manufacture in the iſland. The leaves of this tree, when dried, are of a gloſſy white, which might very eaſily be miſtaken for ſattin: of theſe they make baſkets of ſurpriſing beauty and neatneſs, ſtaining part of the leaves with red or black, and working them into figures very artificially. Our author knew ſome of theſe reſembling ſtraw baſkets, continue full of water for 24 hours, without one drop coming through. They ſell theſe at Loheia and Jidda, the largeſt of them for four commeſh, or ſixpence. This is the employment, or rather amuſement, of the men who ſtay at home; for they work but very moderately at it, and all of them indeed take ſpecial care not to prejudice their health by any kind of fatigue from induſtry.

People of the better ſort, ſuch as the Shekh and his relations, men privileged to be idle, and never expoſed to the ſun, are of a brown complexion. But the common ſort employed in fiſhing, and thoſe who go conſtantly to ſea, are not indeed black but red, and little darker than the colour of new mahogany.

The inhabitants of Dahalac ſeemed to be a ſimple, fearful and inoffenſive people. It is the only part of Africa or Arabia (call it which you pleaſe) where you ſee no one carry arms of any kind; neither gun, knife, nor ſword, is to be ſeen in the hands of any one. Whereas, at Loheia, and on all the coaſt of Arabia, and more particularly at Yambo, every perſon goes armed; even the porters, naked, and groaning under the weight of their burden and heat of the day, have yet a leather belt, in which they carry a crooked knife, ſo monſtrouſly long, that it needs a particular motion and addreſs in walking not to lame the bearer. This was not always the caſe at Dahalac; ſeveral of the Portugueſe, on their firſt arrival here, were murdered, and the iſland often treated ill in revenge by the armaments of that nation. The men ſeemed healthy. They told our author they had no diſeaſes among them, unleſs ſometimes in ſpring, when the boats of Yemen and Jidda bring the ſmall-pox among them, and very few eſcape with life that are infected. He did not obſerve among them a man that ſeemed to be ſixty years old; from which he inferred that they are not long livers, though the air ſhould be healthy, as being near the character contemplated with admiration and delight (of late, indeed, with a mixture of anxiety and fear), as the temple of piety, as the genuine ſource of greater happineſs and freedom, to a larger portion of mankind than ever flowed from any government upon earth.

“ Ill indeed can the times bear the loſs of ſuch an affectionate patriot and the guardian of the laws of his country. But we muſt not murmur at the will of Providence, which in its mercy ‘ may have withdrawn the good man from the evil to come.’ In mercy, I ſay, to him, whoſe righteous ſpirit was ſo deeply grieved when ‘ he ſaw the wicked rage, and the people imagine a vain thing.”

Such is the memorial which, in the hour of recent ſorrow, followed this excellent man to the grave; and we believe it will yet be allowed to be juſt by all who had the happineſs of his Lordſhip's acquaintance, and are what he was, friends to the beſt intereſts of mankind.

This ſketch of the life of Lord Hailes would be more imperfect than even it is, if we could not ſubjoin to it a catalogue of his publications, of which the greater part are exceedingly curious. We call them *publications*, becauſe he employed almoſt as much of his time in republiſhing old and uſeful books as in preparing for the preſs his own valuable works.

Beſides his eſſays in the papers called *The World* and *The Mirror*, which are well known and univerſally admired, his Lordſhip publiſhed the following works:

Sacred Poems, or a Collection of Tranſlations and Paraphraſes from the Holy Scriptures; by various authors, Edinburgh, 1751, 12mo. Dedicated to Charles Lord Hope, with a preface of ten pages.

The Wiſdom of Solomon, Wiſdom of Jeſus the Son of Sirach, or Eccleſiaſticus, 12mo, Edin. 1755.

Select Diſcourſes (in number nine), by John Smith, late Fellow of Queen's College, Cambridge, 12mo, 291 pages. Edin. 1756; with a preface of five pages, “ many quotations from the learned languages tranſlated,—and notes added, containing alluſions to ancient mythology, and to the erroneous philoſophy which prevailed in the days of the author,—various inaccuracies of ſtyle have been corrected, and harſh expreſſions ſoftened.”

A Diſcourſe of the unnatural and vile Conſpiracy attempted by John Earl of Gowry and his Brother, againſt his Majeſty's perſon, at St Johnſtoun, upon the 5th of Aug. 1600. No date of the republication, but the edition and notes ſuppoſed by Lord Hailes, 12mo, 1757.

A Sermon, which might have been preached in Eaſt Lothian upon the 25th day of October 1761, on Acts xxvii. 1, 2. “ The barbarous people ſhewed us no little kindneſs.” Edin. 1761, pp. 25, 12mo. “ Occaſioned by the country people pillaging the wreck of two veſſels, viz. the Betſy, Cunningham, and the Leith Packet, Pitcairn, from London to Leith, caſt away on the ſhore between Dunbar and North Berwick. All the paſſengers on board the former, in number 17, periſhed; five on board the latter, October 16. 1761.”—A moſt affecting diſcourſe, admirably calculated to convince the offenders!

Memorials and Letters relating to the Hiſtory of Britain, in the reign of James I. publiſhed from the originals, Glaſgow, 1762.—Addreſſed to Philip Yorke, Viſcount Royſton, pp. 151. “ From a collection in the advocate's library, by Balfour of Denmyln.” The preface of four pages, ſigned Dav. Dalrymple.

The Works of the ever-memorable Mr John Hailes of Eaton, now firſt collected together in 3 vols, Glaſgow, 1765; preface of three pages. Dedicated to William (Warburton), Biſhop of Glouceſter. “ The edition ſaid to be undertaken with his approbation; obſolete words altered, with corrections in ſpelling and punctuation.”

A ſpecimen of a book intitled “ Ane Compendious Booke of Godly and Spiritual Sangs, collectit out of ſundrie parts of the Scripture, with ſundrie of other Ballates changed out of prophaine Sanges, for avoyding of Sin and Harlotrie, with augmentation of ſundry Gude and Godly Ballates, not contained in the firſt edition. Edinburgh, printed by Andro Hart,” 12mo. Edin. 1765, pp. 42; with a Gloſſary of four pages.

Memorials and Letters relating to the Hiſtory of Britain in the reign of Charles I. publiſhed from the originals, Glaſgow, 1766, pp. 189. Preface of ſix pages, ſigned Dav. Dalrymple, chiefly collected by Mr Wodrow, author of the Hiſtory of the Church of Scotland. Inſcribed to Robert Dundas of Arniſton, Lord Preſident of the Court of Seſſion.

An account of the preſervation of Charles II. after the Battle of Worceſter, drawn up by himſelf; to which are added, his Letters to ſeveral perſons. Glaſgow, 1766, pp. 196, from the MSS. of Mr Pepys, dictated to him by the king himſelf, and communicated by Dr Sandby, maſter of Magdalen College. The letters are collected from various books; ſome of them now firſt publiſhed, communicated by the tutors of the Duke of Hamilton, by the Earl of Dundonald, &c. The preface of four pages, ſigned Dav. Dalrymple, dedicated to Thomas Holles, Duke of Newcaſtle, chancellor of the univerſity of Cambridge.

The Secret Correſpondence between Sir Robert Cecil and James VI. 12mo, 1766.

A Catalogue of the Lords of Seſſion, from the Inſtitution of the College of Juſtice in the year 1532, with Hiſtorical Notes. *Suum cuique—rependet poſteritas.* Edin. 1767, 4to, pp. 26.

The Private Correſpondence of Dr Francis Atterbury, Biſhop of Rocheſter, and his friends, in 1725, never before publiſhed. Printed in 1768, 4to. Advertiſement, pp. 2. Letters, pp. 10. A fac ſimile of the firſt from Biſhop Atterbury to John Cameron of Lochiel, to prove their authenticity.

An Examination of ſome of the Arguments for the High Antiquity of *Regiam Majeſtatem*; and an Inquiry into the authenticity of the *Leges Malcolmi*; by Sir David Dalrymple, 4to, pp. 52. Edin. 1769.

Hiſtorical Memoirs concerning the Provincial Councils of the Scottiſh Clergy, from the earlieſt Accounts to the Æra of the Reformation; by Sir David Dalrymple. Edinburgh, 1769, 4to, pp. 41.—*Nota*, Having no high opinion of the popularity of his writings, he prefixes to this work the following motto. “ Si delectamur quum ſcribimus quis eſt tam invidus qui ab oe nos abducat? ſin laboramus quis eſt qui alienæ modum ſtatuat induſtriæ.”—*Cicero*.

Canons of the Church of Scotland, drawn up in the Provincial councils held at Perth, A. D. 1242, and 1269. Edinburgh, 1769, 4to, pp. 48.

Ancient Scottiſh Poems, publiſhed from the MS. of George Bannatyne, 1568. Edin. 1770, 12mo. Preface ſix pages; Poems pp. 221; very curious notes pp. 92; gloſſary and liſts of paſſages and words not underſtood, pp. 14.

The additional Caſe of Elizabeth, claiming the title and dignity of Counteſs of Sutherland; by her Guardians. Wherein the facts and arguments in ſupport of her claim are more fully ſtated, and the errors in the additional caſes for the other claimants are detected, 4to.——This ſingularly learned and able caſe was ſubſcribed by Alexander Wedderburn (preſent Lord Chancellor), and Sir Adam Ferguſſon, but is the well-known work of Lord Hailes. It ought not to be regarded merely as a law paper of great ability, but as a treatiſe of profound reſearch into the hiſtory and antiquity of many important and general points of ſucceſſion and family hiſtory. Introduction, pp. 21; the firſt four chapters, pp. 70; the fifth and ſixth chapters, pp. 177.

Remarks on the Hiſtory of Scotland, by Sir David Dalrymple.—"Utinam tam facile vera invenire poſſem quam falſa convincere." *Cicero.*—Edin. 1773, inſcribed to George Lord Lyttleton, in nine chapters, pp. 284. 12mo..

Huberti Langueti Epiſtolæ ad Philippum Sydneium Equitem Anglum, accurante D. Dalrymple de Hailes, Eq. Edinburgh, 1776, 8vo. Inſcribed to Lord Chief Baron Smythe.—Virorum Eruditorum Teſtimonia de Langueto, pp. 7. Epiſtolæ, pp. 289. Index Nominum, pp. 41.

Annals of Scotland, from the Acceſſion of Malcolm III. ſurnamed Canmore, to the Acceſſion of Robert I. by Sir David Dalrymple. Edin. 1776, pp. 311. Appendix, pp. 51.

Tables of the Succeſſion of the Kings of Scotland, from Malcolm III. to Robert I. their marriages, children, and time of their death; and alſo of the Kings of England and France, and of the Popes who were their contemporaries.

Chronological Abridgement of the Volume, pp. 30. The Appendix contains eight diſſertations: 1. Of the law of Evenus and Mercheta Mulierum, pp. 17. 2. A commentary on the 22d ſtatute of William the Lion, pp. 8. 3. Of the 18th Statute of Alexander III. pp. 5. 4. Bull of Pope Innocent IV. pp. 6. 5. Of Walter Stewart, Earl of Menteeth, 1296, pp. 7. 6. Of M'Duff, ſlain at Falkirk, in 1298, pp. 3. 7. Of the death of John Comyn, 10th February, 1305, pp. 4. 8. Of the origin of the houſe of Stuart, pp. 6.

Annals of Scotland from the acceſſion of Robert I. ſurnamed Bruce, to the Acceſſion of the Houſe of Stuart; by Sir David Dalrymple, Edin. 1779, 4to, pp. 277. Appendix, pp. 54, containing, 1. Of the manner of the death of Marjory, daughter of Robert I. pp. 7. 2. Journal of the campaign of Edward III. 1327 pp. 9. 3. Of the genealogy of the family of Seton in the 14th century. 4. Liſt of the Scottiſh commanders at the battle of Hallidon, 19th July, 1383, pp. 11. 5. Whether Edward 3d put to death the ſon of Sir Alexander Seton, pp. 8. 6. Liſt of the Scottiſh commanders killed or made priſoners at the battle of Durham, pp. 8. 7. Table of kings, p. 1. 8. Corrections and additions to volume i, pp. 16. Chronological abridgement of the volume, pp. 39.

Account of the Martyrs of Smyrna and Lyons, in the 2d century, 12mo, with explanatory notes, Edin. 1776. Dedicated to Biſhop Hurd, pp. 68. Notes and illuſtrations, pp. 142. This is a new and correct verſion of two moſt ancient epiſtles, the one from the church at Smyrna to the church at Philadelphia. The other from the Chriſtians at Vienna and Lyons to thoſe in Aſia and Phrygia—their antiquity and authenticity are undoubted. Great part of both is extracted from Euſebius's Eccleſiaſtical Hiſtory. The former was firſt completely edited by Archbiſhop Uſher. The author of the notes ſays of them, with his uſual and ſingular modeſty, "That they will afford little new or intereſting to men of erudition, though they may prove of ſome benefit to the unlearned reader." But the erudition he poſſeſſed in theſe branches is ſo rare, that this notice is unneceſſary. They diſplay much uſeful learning and ingenious criticiſm, and breathe the moſt ardent zeal, connected with an exemplary knowledge of Chriſtianity. N. B. This is the firſt volume of the remains of Chriſtian Antiquity.

Remains of Chriſtian Antiquity, with explanatory notes, vol. ii. Edin. 1778, 12mo. Dedicated to Dr Newton biſhop of Briſtol. Preface, pp. 7. This volume contains the trial of Juſtin Martyr and his companions, pp. 8. Epiſtle of Dionyſius biſhop of Alexandria, to Fabius biſhop of Antioch, pp. 16. The trial and execution of Cyprian biſhop of Carthage, pp. 8. The trial and execution of Fructuoſus biſhop of Tarracona in Spain, and of his two deacons, Augurius and Eulogius, pp. 8. The Maiden of Antioch, pp 2. Theſe are all newly tranſlated by Lord Hailes from Ruinart, Euſebius, Ambroſe, &c. The notes and illuſtrations of this volume extend from p. 47 to 165, and diſplay a moſt intimate acquaintance with antiquity, great critical acumen, both in elucidating the ſenſe, and detecting interpolations; and above all, a fervent and enlightened zeal, in vindicating ſuch ſentiments and conduct as are conformable to the word of God againſt the malicious ſarcaſms of Mr Gibbon. To this volume is added an appendix of pp. 22, correcting and vindicating certain parts of vol. i.

Remains of Chriſtian Antiquity, vol. iii. Edin. 1780. Dedicated to Thomas Balguy, D. D. Preface, pp. 2. It contains the Hiſtory of the martyrs of Paleſtine in the 3d century, tranſlated from Euſebius, pp. 94. Notes and illuſtrations, pp. 135, in which Mr Gibbon again comes, and more frequently, under review.—The partiality and miſrepreſentations of this popular writer are here expoſed in the calmeſt and moſt ſatisfactory manner.

Pity it is that Lord Hailes ſhould have printed and publiſhed theſe valuable volumes, and indeed moſt of his other works, at his own expence; and diſperſed them ſo liberally to his friends, that they have been little circulated among any other.

Octavius, a Dialogue, by Marcus Minucius Felix. Edin. 1781, pp. 16. Preface.—The ſpeakers are, Cæcilius a Heathen, Octavius a Chriſtian; whoſe arguments prevail with his friend to renounce Paganiſm and become a Chriſtian proſelyte. Notes and illuſtrations, pp. 120.

Of the manner in which the Perſecutors Died; a Treatiſe by L. C. F. Lactantius, Edin. 1782. Inſcribed to Dr Porteous biſhop of Cheſter (preſent biſhop of London). Preface, pp. 37. in which it is

proved

Dalrymple. proved that Lactantius is the author. Text, pp. 125. Notes and illuſtrations, pp. 109.

L. C. F. Lactantii Divinarum Inſtitutionum Liber Quintus ſeu de Juſtitia, 1777.

Diſquiſitions concerning the Antiquity of the Chriſtian Church. Glaſgow, 1783. Inſcribed to Dr Halifax, biſhop of Glouceſter, pp. 194.—This ſmall original and moſt excellent work, conſiſts of ſix chapters. Chap. 1. A commentary on the conduct and character of Gallio. Acts xviii. 5, 12, 17.—Chap. 2. Of the time at which the Chriſtian religion became publicly known at Rome.—Chap. 3. Cauſe of the perſecution of the Chriſtians under Nero. In this the hypotheſis of Mr Gibbon, vol. i. 4to, p. 641, is examined.—Chap. 4. Of the eminent Heathen writers who are ſaid (by Gibbon) to have diſregarded or contemned Chriſtianity, viz. Seneca, Pliny ſen. Tacitus, Pliny jun. Galen, Epictetus, Plutarch, Marcus Antonius. To the admirers of Heathen philoſophers, and to thoſe eſpecially who ſtate between them and the Chriſtian doctrine any conſanguinity, this chapter is earneſtly recommended.—Chap. 5. Illuſtration of a conjecture by Gibbon, reſpecting the ſilence of Dio Caſſius concerning the Chriſtians. In this chapter, with extreme impartiality, he amplifies and ſupports an idea of Mr Gibbon on this head. Chap. 6. Of the circumſtances reſpecting Chriſtianity that are to be found in the Auguſtan hiſtory.

It ſeems very probable that the cloſe attention which Lord Hailes appears to have given to ſuch ſubjects, was in ſome meaſure the effect of the miſtakes and partiality of Gibbon. In no one work, from 1776, the date of Mr Gibbon's firſt publication, has he omitted to trace this unfair and inſinuating author; but in 1786 he came forth of ſet purpoſe with the moſt able and formidable reply, which he has received, intitled, "An Inquiry into the Secondary Cauſes which Mr Gibbon has aſſigned for the rapid growth of Chriſtianity; by Sir David Dalrymple." Edin. 1786; gratefully and affectionately aſcribed to Richard (Hurd) biſhop of Worceſter, 4to, pp. 213. In five chapters.

Sketch of the Life of John Barclay, 4to, 1786.

Sketch of the Life of John Hamilton, a Secular Prieſt, 4to (one of the moſt ſavage and bigotted adherents of Popery, who lived about A. D. 1600.)

Sketch of the Life of Sir James Ramſay, a general officer in the armies of Guſtavus Adolphus king of Sweden, with a head.

Life of George Leſlie (an eminent capuchin friar in the early part of the 17th century), 4to, pp. 24.

Sketch of the Life of Mark Alex. Boyd, 4to.

Theſe lives were written and publiſhed as a ſpecimen of the manner in which a *Biographia Scotica* might be executed; and it is likely that Lord Hailes ſelected purpoſely the leaſt intereſting.

The Opinions of Sarah Ducheſs Dowager of Marlborough, publiſhed from her original MSS. 1788, 12mo, pp. 120. (with a few foot notes by Lord Hailes, in which he corrects the ſplenetic partiality of her Grace).

The Addreſs of Q. Sept. Tertullian to Scapula Tertullus, Proconſul of Africa, tranſlated by Sir David Dalrymple, 12mo. Edin. 1790, inſcribed to Dr John Butler, biſhop of Hereford; preface, pp. 4; tranſlation pp. 18; original, pp. 13; notes and illuſtrations, pp. 135.

This addreſs contains many particulars relating to the church after the third century. The tranſlator has rejected all words and phraſes of French origin, and written entirely in the Anglo Saxon dialect. In the courſe of the notes many obſcurities of the original, not adverted to by other commentators, are explained. Some ſtrange inaccuracies of Mr Gibbon are alſo detected, not included in the miſrepreſentations of his two famous chapters.

This was the laſt work of this truly learned, reſpectable and uſeful man. Whether he left behind him any thing elſe finiſhed for the preſs, is known only to his friends. We have repeatedly heard that he was engaged in examining the authenticity of the books of the New Teſtament, and that, with the exception of two or three, he found every verſe contained in it in the writings of the firſt three centuries. This ſeems indeed to have been an object in all his works; for, at the end of each of his tranſlations and editions of the primitive Chriſtian writers. A table is given of paſſages quoted or mentioned by them. If his Lordſhip completed any work of this kind, it ſhould not be withheld from the public. We may indeed be told that its utility in a great meaſure ſuperceded by the laborious collection of Lardner (B), and the more elegant work of Paley (C); but not to mention the prejudices generally entertained againſt Lardner on account of his evident bias to Unitarianiſm, it would ſurely be proper, in the preſent age of wild opinions, to ſhew the multitude, who are guided by authority, how important a ſubject the Chriſtian religion was deemed by this learned and accompliſhed layman.

DALTON, a fine townſhip in Berkſhire co. Maſſachuſetts, having Pittsfield on the W. and contains 554 inhabitants. The ſtage road from Boſton to Albany, runs through it. Dalton was incorporated in 1784, and lies 135 miles W. by N. of Boſton, and about 35 the ſame courſe, from Northampton.—*Morſe.*

DALTON, a townſhip in Grafton co. New-Hampſhire, firſt called Apthorpe, was incorporated in 1784, and has only 14 inhabitants. It lies on the E. bank of Connecticut river at the 15 mile falls, oppoſite Concord, in Eſſex co. Vermont.—*ib.*

DAMIENS (Robert François), as he poſſeſſed neither literature nor ſcience, is not, ſtrictly ſpeaking, intitled to notice in this Work. His character, however, was ſo extraordinary, and the noiſe which he made in the world ſo great, that a ſhort account of his life will probably be acceptable to a numerous claſs of our readers.

He was born in 1714, in the ſuburbs of Arras, called *St Catharines*. His infancy announced what he would one day become; for ſuch were his wickedneſs and knaveries, that they procured to him the appellation of *Robert the Devil*.

He ſerved in the army, was at ſeveral engagements, and

(B) See his *Credibility of the Goſpel Hiſtory*, and other works, in 11 vols 8vo.

(C) See his *Evidences of the Criſtian Religion* in 2 vols 8vo.

Damiens.

and at the ſiege of Philipſburgh. On his return to France, he entered in quality of a domeſtic into the college of Jeſuits at Paris, which he left in 1738 to be married.

After having ſerved different maſters in the capital, and poiſoned one of them by a glyſter, he committed a robbery of 240 louis d'ors; which being diſcovered obliged him to abſcond. He lurked, therefore, about five months in the neighbourhood of St Omer, Dunkirk, and Bruſſels, holding always the moſt abſurd purpoſes with regard to the diſputes which at that time divided France. At Poperingue, a ſmall town near Ypres, he was heard to ſay: "If I return to France—Yes, I will return, I will die there, and the greateſt man on earth ſhall die likewiſe, and you ſhall hear news of me!"

It was in the month of Auguſt, 1756, that he uttered theſe extravagant ſentiments. On the 21ſt of December, in the ſame year, being at Faleſque near Arras, at the houſe of one of his relations, he talked in the ſame ſtrain, affirming, "That the kingdom, his wife, and daughter were all ruined!" His blood, his heart, and his head, were at this time in a dreadful ſtate of efferveſcence; and in this ſtate of mind he ſet out for Paris, at which he arrived on the 31ſt day of the ſame month. Having appeared at Verſailles on the firſt day of the year 1757, he took opium for two or three days, probably with a view to invigorate his mind for the horrid purpoſe, which he executed on the 5th of January, about three quarters of an hour after five in the evening.

This execrable parricide ſtruck Louis XV. with a knife in the right ſide, as that monarch, ſurrounded by his courtiers, was entering a carriage to go to Trianon. He was ſeized upon the ſpot; and after having undergone ſome interrogatories at Verſailles, was ſent to Paris to the tower of Montgommeri, where a room was prepared for him, above that which Ravaillac had formerly occupied. The king charged the great court of parliament to inſtitute his proceſs; but notwithſtanding the moſt cruel tortures, which he ſupported with unparalleled firmneſs, they could not get from him a ſingle confeſſion which could lead them to ſuſpect that he had any accomplices. This miſerable wretch proteſted, that if he had been blooded as copiouſly as he wiſhed, he would never have committed the crime. After being cruelly tortured to no purpoſe, he was condemned to die by the ſame puniſhment as the infamous aſſaſſin of Henry IV.

The ſame year, on the 28th of March, which was the day of his execution, he arrived at the *Place de Greve* at a quarter paſt three, looking with a tearleſs eye and a firm countenance on the place and the inſtruments of his puniſhment. They firſt burned his right hand, afterwards tore his fleſh with red hot pincers, and poured melted lead, wax and pitch, into the wounds. They then proceeded to quarter him, the four horſes trying in vain for 50 minutes to diſmember his body. At the end of that time, Damiens being ſtill alive, the executioners cut with knives the fleſh and tendinous joinings of his legs and arms; which they had formerly been obliged to do to Ravaillac. They began with his legs; and even after they were cut, he continued to breathe till his arms were cut in like manner. His puniſhment, from the time he was put upon the ſcaffold to the moment of his death laſted about an hour and an half; during the greater part of which he retained his recollection, and raiſed his head ſeven or eight times to view the horſes and his mangled and burned limbs. In the middle of the moſt violent of the tortures, he even let ſome jokes eſcape him.

That the crime of Damiens was of the deepeſt die, every man but an aſſaſſin like himſelf, will readily acknowledge; but the cruel and lingering puniſhment which was inflicted on him, was ſuch as we think no human being intitled to inflict on another. It was likewiſe impolitic as well as cruel. We can conceive no reaſon for lengthening out any puniſhment, or accompanying it with circumſtances of horror, but to inſpire the ſpectators with a deteſtation of the crime; but a puniſhment too ſevere produces a contrary effect, by withdrawing the attention from the crime to the criminal, and exciting compaſſion for his ſufferings, and indignation againſt the authors of them. Such at leaſt would be its effect in this country; but the minds of Frenchmen ſeem to be differently conſtituted from thoſe of others.

Damiens was rather above the middle ſize; he had a long face, a bold and piercing countenance, and his mouth was a little ſunk. He had contracted a kind of convulſive motion, by a cuſtom he had of ſpeaking to himſelf. He was full of vanity, deſirous of ſignalizing himſelf, curious of novelty, a ſtickler againſt government, though ſilent; converſing with himſelf internally; obſtinate in proſecuting whatever he projected; bold to put it into execution; full of effrontery, and a liar; by turns religious and wicked; committing faults at one time, and immediately after repenting of them, and continually agitated by violent impulſes. "His crime (ſays a writer of genius) coſt us as many groans as improbable projects of his came to light."

How, it has been aſked, could a nation ſo mild and ſo poliſhed as France, or an age which was called philoſophic, produce an aſſaſſin of a king ſo much beloved by his people?

To this queſtion the French author, whoſe work we have tranſlated, anſwers, That at all times there have been wretches who have taken neither of their age nor their country. A man, from the dregs of the people, accuſtomed to crimes, heated by the propoſals of ſome turbulent ſpirits, in the time of conteſts which agitate both the church and the ſtate—will end in a parricide. His brain is heated; he puts himſelf into a ferment of deſpair, produced by miſery, by the fear of the puniſhment his robberies deſerve, and by ſeditious diſcourſes. Agitated more and more by the contradictory movements which his mind experiences, and meditating on a project of this nature, his mind goes aſtray as far as it can, and in the height of his frantic delirium, he perpetrates the crime juſt as a mad dog precipitates himſelf upon the firſt object he meets.

This is perhaps the beſt account which could be given, at the time it was written, of the conduct of Damiens; but ſubſequent events have ſhewn that he did not in fact deviate ſo much as was ſuppoſed from the principles of his age and country, though that age was philoſophic, and that country highly poliſhed. We have ſeen a deſcendant of Louis XV. poſſeſſed of ten times his virtues, and entitled to the love and gratitude of the whole nation, murdered openly in the midſt of his capital, under the *forms* of juſtice, and with circumſtances of atrocity at which the mind of Damiens would perhaps have recoiled. The guilt of an inſane aſſaſſin, who commits a murder in a fit of frenzy, ſinks into inſignificance when compared with that of legiſlators, who coolly departed, not only from every principle of juſtice, but alſo from the very letter of that law which conferred authority on themſelves, to cut off their innocent, their amiable ſovereign.

DAN, a conſiderable river of N. Carolina, which unites with the Staunton, and forms the Roanoke. In May, 1795, a boat 53 feet long, and about 7 tons burden, paſſed from Upper Saura town to Halifax, about 200 miles above Halifax, under the direction of Mr Jeremiah Wade. She brought about 9 hhds. from the above place, 6 of which ſhe diſcharged at St Taminy, 40 miles above Halifax; to which place the river has been cleared by the donations of individuals. From St Taminy to Halifax, ſhe brought about 5000 weight through the falls, which hitherto had been deemed impaſſable. Mr Wade thinks, ſafe navigation for boats of a larger burden may be made at a ſmall expenſe. The famous Burſted-hill ſtands on the bank of the Dan, in Virginia, near the borders of N. Carolina. It appears to have been an ancient volcano. There are large rocks of the lava, or melted matter, from 1000 to 1500 weight, lying on the ſummit of the hill. The crater is partly filled, and covered with large trees.—*Morse.*

DANBURY, a poſt town in the co. of Fairfield, in Connecticut. It was ſettled in 1687, and the compact part of the town contains 2 churches, a court-houſe, and about 60 dwelling-houſes. On its ſmall ſtreams are iron works, and ſeveral mills. Mr Lazarus Beach preſented to the muſeum in New-York city, a quire of paper, made of the aſbeſtos, at his paper mill in Danbury, March, 1792, which the hotteſt fire would not conſume. It lies about 70 miles N. E. of New-York city, and 33 N. W. by W. of New-Haven. This town, with a large quantity of military ſtores, was burnt by the Britiſh on the 26th of April, 1777.—*ib.*

DANBY, a townſhip in Rutland co. Vermont, E. of Pawlet, and contains 1206 inhabitants. It lies about 32 miles N. of Bennington.—*ib.*

DANGEAU (Louis Courcillon de), member of the French academy, Abbe of *Fontaine Daniel* and of Clermont, was born at Paris in January, 1643, and died there the 1ſt of January 1723, aged 80. Few people of family have given ſo much time to the belles lettres, or paid ſuch attention to rendering the ſtudy of them eaſy and agreeable. He deviſed ſeveral methods for rendering of more eaſy acquiſition the knowledge of hiſtory, painting, geography, genealogy, the intereſts of princes, and French grammar. He publiſhed ſome tracts upon each of theſe ſubjects. 1. A new Method of Hiſtorical Geography, 1706, 2 vols. folio; 2. The Principles of Painting, in 14 plates, 1715, 4to.; 3. An Hiſtorical Play of the Kings of France, which is played like that of *Oie*, with a ſmall book explaining the method; 4. Reflections on all the Parts of Grammar, 1684, 12mo. 5. On the Election of the Emperor, 1738, 8vo. The firſt of theſe, however, is his principal work, and a part of the tenth dialogue on the immortality of the ſoul, commonly attributed to the Abbe Choiſi, is likewiſe his. That book is very common; but his other productions are very rare, becauſe he only threw off a few copies for the uſe of his friends.

Dangeau was maſter of many languages; Greek, Latin, Italian, Spaniſh, Dutch, and almoſt all the languages which depend upon theſe. His virtues were equal to his learning. "Full of humanity for the unfortunate (ſays *M d'Alembert*), he diſtributed ſuccour to the indigent, and had the virtue to conceal his good actions. His heart was formed for friendſhip. If he had any faults, they were perhaps too great indulgence for the faults and failings of mankind; a fault which, from its rarity may be called a virtue, and for which few people have any reaſon to reproach themſelves, even towards their friends. He poſſeſſed, in a high degree, that knowledge of men and the world which neither books nor genius alone can give when one has neglected to live with his equals. Rejoicing in the eſteem and confidence which he poſſeſſed in a great degree in France, there could be no better counſellor than he in the moſt important concerns. Yet his noble ſoul, delicate and honourable, was ignorant of deceit; and his prudence was too evident to be taken for fineſſe. Pleaſant and agreeable in converſation, but preferring truth in all caſes, he never diſputed unleſs there was occaſion to defend it, which he did in ſuch a firm manner as to give ſome people an idea that he was obſtinate in diſputing, which is ſeldomer found among men than a cool and culpable indifference."

Dangeau (Philippe de Courcillon Marquis de), brother to the former, was born in 1638. The elegance of his wit and perſon advanced him at the court of Louis XIV. and his decided taſte for letters procured him a place in the French academy, and in that of ſciences. He died at Paris in 1720, at the age of 82, chevalier of the order of the king, and grand maſter of the royal and military orders of our lady of Mont Carmel and of St Lazarus of Jeruſalem. When he was inveſted with this laſt dignity, he paid more attention than was formerly done to the chooſing of chevaliers; he renewed the ancient pomp of their admiſſion, which the public, always malicious, ridiculed. But that which ſhould have ſcreened him from ridicule was, that it procured him the foundation of 25 commanderies, and he employed the revenues to bring up 12 young men of the beſt nobility in France. Even envy then excuſed his elevation. At the court (ſays Fontenelle), where credit is never given to probity and virtue, he held always a fair and unblemiſhed reputation. His converſation, his manners were all regulated by a politeneſs, which was not the conſequence merely of his aſſociating with good company, but the offspring of an obliging and benevolent heart. We ſhould paſs over in him, on account of his honourable manners, the deſire he had to be a great lord. Madame de Monteſpan, who did not believe he could play this part, uſed to ſay, in a malicious manner, that one could not help loving and deſpiſing him at the ſame time. He married, firſt *Françoiſe Morin*, ſiſter to the Marechal d'Eſtrées, and afterwards the Counteſs de *Leuveſtein*, of a very noble houſe, but not opulent.

There are extant manuſcript memoirs by the Marquis Dangeau, in which there are ſeveral curious anecdotes of Voltaire, Henault, and Beaumelle. Dangeau, however, did not always write theſe memoirs; which, according to the author of the age of Louis XIV. were compiled by an old valet de chambre, who inſerted in them without order, every ridiculous thing which he heard in the antichamber, or read in the gazettes. There ſtill remains a ſmall work of Dangeau's, which paints, in an intereſting manner, Louis the XIV. as he was in the midſt of his court.

DANVERS, a townſhip in Eſſex co. Maſſachuſetts, adjoining Salem on the N. W. in which it was formerly comprehended by the name of Salem village. It conſiſts of two pariſhes, and contains 2425 inhabitants, and was incorporated in 1757. The moſt conſiderable and compact ſettlement in it, is formed by a continuation of the principal ſtreet of Salem, which extends more than two miles toward the country, having many work ſhops of mechanics, and ſeveral for retailing goods. Large quantities of bricks and coarſe earthen ware are manufactured here. Another pleaſant and thriving ſettlement is at the head of Beverly river, called New-Mills; where a few veſſels are built and owned. The town of Danvers receives an annual compenſation of £.10 from the proprietors of Eſſex bridge, for the obſtruction of the river.—*Morse*.

DANVILLE, a thriving poſt town in Mercer co. and formerly the metropolis of Kentucky, pleaſantly ſituated in a large, fertile plane, on the S. W. ſide of Dick's river, 35 miles S. S. W. of Lexington. It conſiſts of about 50 houſes, and a Preſbyterian church. From Leeſburg to Danville, the country, for the firſt 20 miles, is of an inferior rate for lands in this country; but round Lexington, and from Leeſburgh to Lexington and Boonſborough, is the richeſt land in the country. It is 40 miles S. by E. of Frankfort, 83 from Louiſville, 201 from Hawkins in Tenneſſee, and 830 from Philadelphia. N. lat. 37. 30. W. long. 85. 30.—*ib.*

Danville, a very thriving townſhip in Caledonia co. Vermont. It was a wilderneſs, without ſo much as a ſingle family, a few years ago, and now contains 574 inhabitants. It lies 8 miles N. W. of Barnet.—*ib.*

DARBY, a ſmall town in Delaware co. Pennſylvania, on the E. ſide of Darby Creek. It contains about 50 houſes, and a Quaker meeting-houſe, and lies 7 miles S. W. by W. of Philadelphia. There are two townſhips of this name, in the county, called Upper and Lower, from their relative ſituation.—*ib.*

DARCY (Count), an ingenious philoſopher and mathematician, was born in Ireland in the year 1725; but his friends being, like many other great and good families at that period, attached to the houſe of Stuart, he was at 14 years of age ſent to France, where he ſpent the reſt of his life. Giving early indications of a genius for ſcience, he was put under the care of the celebrated Clairaut (ſee Clairaut, *Encycl.*) under whoſe tuition he improved ſo rapidly in the mathematics, that at 17 years of age, he gave a new ſolution of the problem concerning the curve of equal preſſure in a reſiſting medium. This was followed the year after by a determination of the curve deſcribed by a heavy body, ſliding by its own weight along a moveable plane, at the ſame time that the preſſure of the body cauſes a horizontal motion in the plane.

Though Darcy ſerved in the war of 1744, he found leiſure, during the buſtle of a military life, to ſend two memoirs to the academy: the firſt of theſe contained a general principle in mechanics, that of the preſervation of the rotatory motion; a principle which he again brought forward in 1750, by the name of the principle of the preſervation of action. He was taken priſoner in this war by the Engliſh: and ſuch was either the reſpect paid to ſcience, or the mercy of the cabinet of St James's, that he was treated, not as an Iriſh rebel, but as a French ſubject fighting for his king and his country.

In 1760, Darcy publiſhed An Eſſay on Artillery, containing ſome curious experiments on the charges of gunpowder, &c. &c. and improvements on thoſe of the ingenious Robbins; a kind of experiments which our author carried on occaſionally to the end of his life. In 1765, he gave to the public the moſt ingenious of all his works his Memoir on the Duration of the Senſation of Sight, in which he endeavours to prove, and indeed completely proves, that a body may ſometimes paſs by our eyes without producing a ſenſation attended with conſciouſneſs, or marking its preſence, otherwiſe than by weakening the brightneſs of the object which it may chance to cover in its paſſage. If in this work he ſhall be thought to have taken hints from Dr Hartley, it is not perhaps too much to ſay, that ſome of our moſt celebrated writers on viſion have ſince been beholden to Darcy. No man indeed has cauſe to be aſhamed of being indebted to him; for all his works diſplay in an eminent degree the union of genius and philoſophy; but as he meaſured every thing upon the largeſt ſcale, and required extreme accuracy in experiment, neither his time, fortune, nor avocations, allowed him to execute more than a very ſmall part of what he projected.

In his diſpoſition, Darcy was amiable, ſpirited, lively, and a lover of independence; a paſſion to which he nobly ſacrificed, even in the midſt of literary ſociety.—He died of a cholera morbus in 1779, at 54 years of age. He was admitted of the French academy in 1749, and was made penſioner-geometrician in 1770. His eſſays printed in the Memoirs of the Academy of Sciences, are various and very ingenious, and are contained in the volumes for the years 1742, 1747, 1749, 1750, 1751, 1752, 1753, 1754, 1758, 1759, 1760, 1765, and in tom 1. of the Savans Etrangers.

DARIEN, Gulf of, runs S. eaſterly into Terra Firma. On the eaſtern ſide of its mouth, is the town of St Sebaſtian.—*Morse*.

Darien, a town in Liberty co. Georgia, by the heights of which glides the N. channel of Alatamaha river, about 20 miles above Sapelo Iſland, and 10 below Fort Barrington. It lies 47 miles S. S. W. of Savannah. N. lat. 31. 23. W. long. 80. 14.—*ib.*

DARLINGTON, the moſt ſouthern county of Cheraws diſtrict, S. Carolina; bounded S. and S. W. by Lynch's creek. It is about 35 miles long, and 21 broad.—*ib.*

DARTMOUTH, a town in Grafton co. New-Hampſhire, north weſt of the foot of the White Mountains; 33 miles N. E. of Haverhill, New-Hampſhire, and 87 N. weſterly of Portſmouth. It contains 111 inhabitants, and was incorporated in 1772.—*ib.*

Dartmouth, a thriving ſea-port town in Briſtol co. Maſſachuſetts, ſituated on the W. ſide of Accuſhnet river, 70 miles ſoutherly of Boſton. It was incorporated in 1664, and contains 2499 inhabitants. N. lat. 41. 37. W. long. 70. 52.—*ib.*

Dartmouth, a town in Elbert co. Georgia, ſituated on the peninſula formed by the confluence of Broad and Savannah rivers, 2 miles from Fort James Dartmouth, which is a mile below Charlotte Fort. The town and fort derive their names from James, earl of Dartmouth, whoſe influence in the Britiſh councils obtained from the king, a grant and powers to the Indian trading company in Georgia to treat with the Creeks, for the territory called the *New Purchaſe*, ceded in diſcharge of debts due to the traders. This tract contains about 2,000,000 of acres, lying upon the head of the Great Ogechee, between the banks of the Savannah and Alatamaha, touching on the Oconee, including all the waters of Broad and Little rivers. This territory comprehends a body of excellent, fertile land, well watered by innumerable rivers, creeks and brooks. —*ib.*

DATA of Euclid, the firſt in order of the books that have been written by the ancient geometricians, to facilitate and promote the method of reſolution or analyſis. In general, a thing is ſaid to be given which is either actually exhibited, or can be found out, that is, which is either known by hypotheſis, or that can be demonſtrated to be known: and the propoſitions in the book of Euclid's data, ſhew what things can be found out or known, from thoſe that by hypotheſis are already known: ſo that in the analyſis or inveſtigation of a problem, from the things that are laid down as given or known, by the help of theſe propoſitions, it is demonſtrated that other things are given, and from theſe laſt that others again are given, and ſo on, till it is demonſtrated that that which was propoſed to be found out in the problem is given; and when this is done, the problem is ſolved, and its compoſition is made and derived from the compoſitions of the data which were employed in the analyſis. And thus the data of Euclid are of the moſt general and neceſſary uſe in the ſolution of problems of every kind.

Marinus, at the end of his preface to the data, is miſtaken in aſſerting that Euclid has not uſed the ſynthetical, but the analytical method in delivering them: for though in the analyſis of a theorem, the thing to be demonſtrated is aſſumed in the analyſis; yet in the demonſtrations of the data, the thing to be demonſtrated, which is, that ſomething is given, is never once aſſumed in the demonſtration; from which it is manifeſt, that every one of them is demonſtrated ſynthetically: though indeed if a propoſition of the data be turned into a problem, the demonſtration of the propoſition becomes the analyſis of the problem. *Simpſon's Preface to his edition of the Data.*

DAUBENTON (William), who made ſo much noiſe early in this century, was born at Auxerre. He followed King Philip V. whoſe confeſſor he was, into Spain. He had the greateſt influence with that prince until the courtiers, jealous of his power, prevailed upon the king to ſend him from court in 1706. By dint of ſolicitations, however, he was recalled in 1716, reinſtated in his office, and then enjoyed more power than before. It is ſaid, that when Philip V. diſguſted with his throne, wiſhed to abdicate it, he confided his deſign to Daubenton; that the latter, fearing that he ſhould be obliged to follow him to his retreat, diſcovered this ſecret to the Duke of Orleans, regent of France, who was at that time projecting the double marriage of Mademoiſelle de Montpenſier his daughter, with the Prince of the Aſturias, and that of Louis the XV. with the infanta, five years of age. It is added, that the Jeſuit believed it would be for the intereſt of the Duke of Orleans to diſſuade Philip from his purpoſe; that the Duke of Orleans ſent the confeſſor's letter to the king, who ſhewed it to Daubenton, without ſaying a ſingle word; that the confeſſor put a very different conſtruction upon it; that an apoplexy ſeized him on going out of the chamber; and that he died a ſhort time after in 1723; in the 75th year of his age. This ſtory (for the truth of which we will avouch ſtill the leſs, that it is not mentioned by the Marſhal de Noailles in his memoirs) is related by the author of the Age of Louis XV. who quotes the civil hiſtory of Bellando, page 306, Part IV. It is only clear from the memoirs of Noailles, that Daubenton oppoſed the abdication of the King of Spain. The Abbe Groſier, in a letter inſerted in the *Année Litteraire* (1777, N° 18), denies, 1*mo*, That Daubenton had revealed to the regent any ſecret entruſted to him by Philip V. in confeſſion. 2*do*, That this Jeſuit died, as Voltaire makes him from the authority of Bellando, an inaccurate hiſtorian, whoſe works were ſuppreſſed in Spain. 3*tio*, He pretends that Daubenton, far from being a man of intrigue, an ambitious monk, and capable of oppoſing the abdication of Philip, in order to prevent himſelf from being removed from court, had ſolicited permiſſion to leave it ſeveral years before. We refer the reader to that letter, which deſerves to be read for the ſound criticiſm which it contains. This Jeſuit had preached with ſome ſucceſs. There are extant ſome tolerable funeral orations of his, and a life of St. Francois Regis, 12mo.

DAUPHIN, Fort, a juriſdiction, fort and ſea-port town in the N. part of the iſland of St Domingo. This diviſion contains 5 pariſhes. Its exports from Jan. 1, 1789 to Dec. 31 of the ſame year, conſiſted of ſugar, coffee, cotton, indigo, ſpirits, molaſſes, and tanned hides, in value 35,252 dolls. 13 cents. The town of Fort Dauphin is remarkable for a fountain conſtructed by the orders of M. de Marbois, which coſt 10,678 dollars. N. lat. 19. 41.—*Morſe.*

Dauphin, an iſland about 10 miles long, in the mouth of Mobile bay, 5 miles from Maſſacre Iſland, with a ſhoal all the way between them. Theſe are ſuppoſed formerly to have been but one, and went by the general name of Maſſacre, ſo called by Monſ. d'Ibberville, from a large heap of human bones found thereon at his landing. It was afterwards called Dauphin Iſland. The W. end, a diſtance of between 3 and 4 miles, is a narrow ſlip of land with ſome dead trees; the reſt is covered with thick pines, which come cloſe to the water's edge on the E. ſide, forming a large bluff. There is the remains of an old French poſt on the S. ſide of the iſland, and of ſome old houſes of the natives. N. lat. 30. 10. W. long. 88. 7. —*ib.*

Dauphin, a fort in the iſland of Cape Breton, round which the French had their principal ſettlement, before they built Louiſburg.—*ib.*

Dauphin *Co.* in Pennſylvania, was formerly contained in that of Lancaſter, until erected into a ſeparate county, March 4, 1785. Its form is triangular; its contents 586,400 acres, and is ſurrounded by the counties of Mifflin, Cumberland, York, Berks, and Northumberland. It is divided into 9 townſhips, the chief in Bennington co. Vermont, and after receiving a number of ſtreams from the adjoining towns, unite on entering Maſſachuſetts; thence winding in an E. direction, it receives North river and empties into Connecticut river, between the townſhips of Greenfield and Deerfield, where it is about 15 rods wide. Excellent tracts of meadow ground lie on its banks.—*ib.*

Deerfield, a very pleaſant town in Hampſhire co. Maſſachuſetts, on the W. bank of Connecticut river, from which the compact part of the town is ſeparated by a chain of high hills. It is in the midſt of a fertile country, and has a ſmall inland trade. The compact part of the town has from 60 to 100 houſes, principally on one ſtreet, and a handſome congregational church. It was incorporated in 1681, and contains 1330 inhabitants; 17 miles N. of Northampton, and 109 N. by W. of Boſton.

The houſe in which the Rev. Mr Williams and his family were captivated by the Indians in the early ſettlement of this town, is ſtill ſtanding, and the hole in the door, cut by the Indians with their hatchets, is ſtill ſhewn as a curioſity. An academy, incorporated in 1797, by the name of "The Deerfield Academy," is eſtabliſhed in this town.—*ib.*

Deerfield, a well ſettled agricultural town in Rockingham co. New-Hampſhire, and was a part of the townſhip of Nottingham, 19 miles S. E. of Concord, and 35 N. W. of Portſmouth. It contains 1619 inhabitants, and was incorporated in 1766.—*ib.*

DEER *Iſland*, an iſland and townſhip in Penobſcot bay, in Hancock co. diſtrict of Maine, containing 682 inhabitants. It was incorporated in 1789, and lies 305 miles N. E. of Boſton.—*ib.*

DEERING, a townſhip in Hillſborough co. New-Hampſhire, incorporated in 1774. It contains 928 inhabitants, and lies 15 miles S. W. of Concord, and 54 miles W. of Portſmouth.—*ib.*

DEFERENS, or **Deferent**, in the ancient aſtronomy, an imaginary circle, which, as it were, carries about the body of a planet, and is the ſame with the eccentric; being invented to account for the eccentricity, perigee, and apogee of the planets.

DEFIANCE, a fort in the N. weſtern territory, ſituated on the point of land formed by the confluence of the rivers of Au Glaize, and the Miami of the lake, nearly half way between Fort Wayne on the Miami, and lake Erie. N. lat. 41. 41. W. long. 84. 43.—*Morſe.*

DEFLECTION, the turning any thing aſide from its former courſe by ſome adventitious or external cauſe. The word is often applied to the tendency of a ſhip from her true courſe by reaſon of currents, &c. which turn her out of her right way. It is likewiſe applied by aſtronomers to the tendency of the planets from the line of their projection, or the tangent of their orbit. See Astronomy in this Supplement.

DEJECTION, in aſtrology, is applied to the planets when in their detriment, as aſtrologers ſpeak, i. e. when they have loſt their force or influence, as is pretended, by reaſon of their being in oppoſition to ſome others which check and counteract them. Or it is uſed when a planet is in a ſign oppoſite to that in which it has its greateſt effect or influence, which is called its *exaltation.* Thus, the ſign Aries being the exaltation of the ſun, the oppoſite ſign Libra is its dejection.

DE LA MARCH, a weſtern water of Illinois river in the N. W. territory. It is 30 yards wide, and navigable 8 or 9 miles.—*Morſe.*

DE LA WAR, a town in King William's co. Virginia, ſituated on the broad peninſula formed by the confluence of the Pamunky and Mattapony. The united ſtream thence aſſumes the name of York river. It lies 20 miles N. by W. of Williamſburg in N. lat. 37. 31. W.—*ib.*

DELAWARE *Bay* and *River.* The bay is 60 miles long, from the cape to the entrance of the river, at Bombay Hook; and occupies a ſpace of about 630,000 acres; and is ſo wide in ſome parts, as that a ſhip, in the middle of it, cannot be ſeen from the land. It opens into the Atlantic N. W. and S. E. between Cape Henlopen on the right, and Cape May on the left. Theſe capes are 18 or 20 miles apart.

Delaware river was called Chihohocki by the aboriginals, and in an old Nurenberg map is named Zuydt river. It riſes by two principal branches in New-York ſtate. The northernmoſt of which, called the Mohawk's or Cookqugo branch, riſes in lake Uſtayantho, lat. 42. 25. and takes a S. W. courſe, and turning S. eaſtwardly, it croſſes the Pennſylvania line in lat. 42.; about 7 miles from thence, it receives the Popachton branch from the N. E. which riſes in the Kaats Kill mountains. Thence it runs ſouthwardly, until it ſtrikes the N. W. corner of New-Jerſey, in lat. 41. 24.; and then paſſes off to ſea through Delaware bay; having New-Jerſey E. and Pennſylvania and Delaware W. The bay and river are navigable from the ſea up to the great or lower falls at Trenton, 155 miles; and are accommodated with buoys and piers for the direction and ſafety of ſhips. A 74 gun ſhip may go up to Philadelphia, 120 miles by the ſhip channel from the ſea. The diſtance acroſs the land, in a S. E. courſe, to New-Jerſey coaſt, is but 60 miles. Sloops go 35 miles above Philadelphia, to Trenton falls; boats that carry 8 or 9 tons, 100 miles farther, and Indian canoes 150 miles, except ſeveral ſmall falls or portages.

It is in contemplation to connect the waters of Cheſapeak bay with thoſe of Delaware river by 4 different canals, viz. Elk river with Chriſtiana creek—Broad creek, another branch with Red Lion creek—Bohemia, a third branch of the Elk, with Apoquinemy creek; and Cheſter river with Duck creek.—*ib.*

Delaware, a ſmall river of Eaſt Florida.—*ib.*

Delaware *Co.* in Pennſylvania, is S. W. of Philadelphia co. on Delaware river. It is about 21 miles in length, and 15 in breadth, containing 115,200 acres, and ſubdivided into 19 townſhips; the chief of which is Cheſter. The number of inhabitants is 9,483. The lands bordering on the Delaware are low, and afford excellent meadow and paſturage; and are guarded from inundations by mounds of earth or dykes, which are ſometimes broken down in extraordinary freſhes in the river. If this happens before cutting the graſs, the crop of hay is loſt for that ſeaſon, and the reparation of the breaches is expenſive to the proprietors. Great numbers of cattle are brought here from the weſtern parts of Virginia, and North-Carolina, to be fattened for ſupplying the Philadelphia market.—*ib.*

Delaware, a new county in the ſtate of New-York, on the head waters of Delaware river, taken from Otſego county.—*ib.*

mining the minute parts of a degree, in ſmall angles, is very much a deſideratum with the practical ſurveyor.

This method of meaſuring diſtances, though plain and ſimple enough, our author illuſtrates by an example: Suppoſe A, fig. 1. (ſee Plate XXI.) the place of the inſtrument; BC the aſſiſtant's ſtaff, with a perpendicular pin at D, to enable the aſſiſtant to hold it in its right poſition; now, if the angle BAC could, by the help of a micrometer, be aſcertained to parts of a minute, the diſtance from A to B, or to C, might be eaſily calculated by the rules of plane TRIGONOMETRY; for which ſee that article in the Encyclopædia.

But this method of aſcertaining diſtances cannot be applied to inacceſſible objects, and it is moreover ſubject to the inconvenience of an aſſiſtant being obliged to go to the object whoſe diſtance is required (an inconvenience almoſt equal to the trouble of actual admeaſurment); therefore the perfection of the ſecond method propoſed, if attainable, is principally to be deſired; namely, that of conceiving the obſervation made on the circumference of a circle, whoſe centre is in the object whoſe diſtance is to be aſcertained; and, none of our inſtruments now in uſe being adapted to this mode of obſervation, a new conſtruction of a mathematical inſtrument is therefore propoſed, the name intended for which is the *dendrometer*.

Our author admits, that this name is not now uſed for the firſt time, though he thinks that the principle has never been applied in practice, for the familiar purpoſe of aſcertaining terreſtrial diſtances, in ſurveying, or otherwiſe, though the ſame principle has been ſo generally and ſucceſsfully applied in determining the diſtance of the heavenly bodies by means of their parallax.

The following principles of conſtruction are propoſed, which may perhaps be otherwiſe varied and improved. O, fig. 2. the object of whoſe diſtance is required: ABCDE the inſtrument *in plano;* BC a teleſcope, placed exactly parallel to the ſide AE; CE an arch of a circle, whoſe centre is at A, accurately divided from E in degrees, &c.; AD an index, moveable on the centre A, with a nonius ſcale at the end D, graduated to apply to the diviſions of the arch; alſo with a teleſcope, to enable the obſerver to diſcriminate the object, or any particular part or ſide thereof, the more accurately. The whole ſhould be mounted on three legs, in the manner of a plain table or theodolite, and furniſhed with ſpirit-tubes to adjuſt it to an horizontal poſition. The inſtrument being placed in ſuch poſition, the teleſcope BC muſt be brought upon the object O, or rather upon ſome particular point or ſide thereof; when, being there faſtened, the index AD muſt be moved till its teleſcope exactly ſtrikes the ſame point of the object; then the diviſions on the arch ED mark out the angle DAE, which will be exactly equal to the angle BOA, as is demonſtrated in the XV. and XXIX. propoſitions of Euclid, Book I.; and the ſide BA, as well as the angles ABO, and BAO, being already known, the diſtance BO or AO may be eaſily determined.

As the perfection of this inſtrument depends altogether upon its accuracy in taking ſmall angles, ſo that accuracy muſt depend, not only upon the inſtrument's being properly fitted with a micrometer, but alſo in ſome meaſure upon the length of the line BA in the figure. That line, therefore might be extended, by the inſtrument being conſtructed to fold or ſlide out to a greater length when in uſe; upon which principle, connected with the application of a micrometer, an accurate and uſeful inſtrument might certainly be conſtructed. To adjuſt ſuch inſtrument for uſe, let a ſtaff be held up at a diſtance, in the manner of fig. 1. exactly equal in length to the diſtance of the two teleſcopes, and the index AD being brought exactly upon the ſide AE, if the two teleſcopes accurately ſtrike either end of the ſtaff, the inſtrument is properly adjuſted.

The conſtruction of a ſimilar inſtrument on the principles of Hadley's quadrant, for naval obſervations, would alſo doubtleſs be an acceptable object in navigation, by enabling the mariner to aſcertain the diſtances of ſhips, capes, and other objects, at a ſingle obſervation; and that, perhaps, with greater accuracy than can be done by any method now in uſe.

For this purpoſe, the following conſtruction is propoſed: ABCDE, fig. 3. the inſtrument *in plano;* O the object whoſe diſtance is required; at A, at C, at E, and at 3, are to be fixed ſpeculums properly framed and fitted, that at 3 having only its lower part quickſilvered, the upper part being left tranſparent to view the object, the ſpeculum at A being fixed obliquely, ſo that a line A 1, drawn perpendicular to its ſurface, may biſect the angle BAC in equal parts; that at C being perpendicular to the line C 2; thoſe at E at 3 being perpendicular to the index E 3, and that at E being furniſhed with a ſight; the arch DC to be divided from D in the manner of Hadley's quadrant; the movement of the index to be meaſured as before by a micrometer; and as the length of the line AE would tend to the perfection of the inſtrument, it may be conſtructed to fold up in the middle, on the line C 2, into leſs compaſs when not in uſe. The inſtrument may be adjuſted for uſe by holding up a ſtaff at a diſtance, as before propoſed, whoſe length is exactly equal to the line AE.

To make an obſervation by this inſtrument, it being previouſly properly adjuſted, the eye is to be applied at the ſight in the ſpeculum E, and the face turned towards the object; when the object being received on the ſpeculum A, is reflected into that at C, and again into that at E, and that at 3 on the index; the index being then moved till the reflected object in the ſpeculum at 3 exactly coincides with the real object in the tranſparent part of the glaſs, the diviſions on the arch D 3, ſubdivided by the micrometer, will determine the angle DE 3 = the angle AOE; from which the diſtance O may be determined as before.

DENNEY's *River*, diſtrict of Maine, 22 miles E. of Machias. The country between this river and Machias, in 1794, was a wilderneſs. The banks of the river were at this time thinly ſettled by a regular and well diſpoſed people.—*Morse.*

DENNIS, a part of Yarmouth in Barnſtable co. Maſſachuſetts, which was incorporated into a townſhip in 1793.—*ib.*

DENOMINATOR OF A RATIO is the quotient ariſing from the diviſion of the antecedent by the conſequent. Thus 6 is the denominator of the ratio 30 to 5, becauſe 30 divided by 5 gives 6. It is otherwiſe called the *exponent* of the ratio.

DENTON, the chief town of Caroline co. in Maryland; ſituated on the E. ſide of Choptank creek, the

E. main branch of Choptank river. It is laid out regularly, and has a few houſes, and lies 7 miles S. of Greenſborough, and 37 S. S. E. of Cheſter.—*Morſe.*

DEPRESSION of a Star, or *Of the Sun,* is its diſtance below the horizon, and is meaſured by an arc of a vertical circle, intercepted between the horizon and the place of the ſtar.

Depression of the Viſible Horizon, or *Dip of the Horizon,* denotes its ſinking or dipping below the true horizontal plane, by the obſerver's eye being raiſed above the ſurface of the ſea; in conſequence of which, the obſerved altitude of an object is by ſo much too great.

DERBY, a townſhip in Orleans co. Vermont, on the N. line of the ſtate, on the E. ſhore of lake Memphremagog.—*Morſe.*

Derby, a town in New-Haven co. Connecticut, on the point of land formed by the confluence of Naugatuck and Houſatonick rivers. This town was ſettled in 1665, under New-Haven juriſdiction, and is now divided into two pariſhes, and has an academy in its infancy. It has a conſiderable trade with the Weſt-Indies for ſo ſmall a town, and a number of mills on the falls of Naugatuck, and ſtreams which fall into it, and iron and other works on Eight-mile river which falls into the Stratford. The Stratford or Houſatonick river is navigable 12 miles to this town.—*ib.*

DEROOBUST, in Bengal, Entire; as an entire diſtrict, oppoſed to Kismut, which ſee.

DERRY, a townſhip in Dauphin co. Pennſylvania, ſituated on the E. ſide of Swatara creek, 2 miles above its confluence with the Suſquehannah, and celebrated for its curious cave.—*Morſe.*

Derry, a townſhip on Suſquehannah river in Pennſylvania. There are two other townſhips of the ſame name in Pennſylvania; the one in Mifflin co. the other in that of Weſtmoreland.—*ib.*

DERRYFIELD, a townſhip in New-Hampſhire, on the E. bank of Merrimack river Hillſborough co. containing 362 inhabitants, and was incorporated in 1751; the ſoil is but indifferent. It is 42 miles W. of Portſmouth.—*ib.*

DESAQUADERO, a river in Peru, S. America, over which the Ynca Huana Capac built a bridge of flags and ruſhes, to tranſport his army to the other ſide, and which remained a few years ſince.—*ib.*

DESAULT (Peter Joſeph), ſurgeon in chief to the Hoſpital of Humanity, formerly the *Hotel-Dieu,* at Paris, was born on the 6th of February, 1744 at Magny Vernois, a village in the neighbourhood of Lure, in the department of Haut Saone (formerly the province of *Franche Comté*) His father and mother were in that ſituation of life which is removed from want, and yet does not diſpenſe with labour; he himſelf was the youngeſt child of a numerous family.

At Lure, under the direction of a private inſtructor, he was taught the firſt rudiments of the Latin tongue; his parents afterwards confided him to the care of the Jeſuits, then almoſt excluſively entruſted with the education of youth in the public ſchools. This celebrated ſociety, prompt in diſcovering, as expert at developing, and adroit in appropriating talents, ſoon diſtinguiſhed the young ſtudent from the crowd; and he in his turn, was not diſpleaſed with the life he led in one of their ſeminaries.

On the completion of his ſtudies his father, who had deſtined him for the church, intimated a wiſh that he ſhould apply himſelf to theology; but his genius had taken a different direction, and he was averſe to the profeſſion of an eccleſiaſtic: in ſhort, young Deſault declared that he was determined to betake himſelf to the ſtudy of the healing art, and, after a long and ineffectual reſiſtance on the part of his family, he was ſent to Béfort, in order to ſerve an *apprenticeſhip,* as it was then termed, in the military hoſpital of that place. He accordingly ſpent three years there, during which he acquired ſome knowledge of anatomy, attended to the dreſſing of the patients, and endeavoured to ſupply, by his own obſervations, what was wanting in his inſtruction.

In the midſt of theſe profeſſional labours, his mind frequently rambled towards another ſcience but little connected with ſurgery: this was mathematics, the elements of which he had acquired among the Jeſuits. His progreſs in this favourite ſtudy was rapid; but he fell into one of the many errors ſo common among the phyſicians of that day: this conſiſted in a falſe application of the rules of geometry to the laws of the animal economy.

He not only peruſed with avidity the treatiſe of Borelli *De Motu Animalium,* but actually tranſlated the whole of it, and even added a commentary ſtill more abundant in calculation than that of the celebrated profeſſor of Naples.

His ſucceſs in a branch of phyſiology ſo much cultivated at that time, attracted the attention of one of his ſuperiors, a zealous partizan of the doctrine of the mechanicians who wiſhed to attach him to his perſon; but his deſire of fame required a more extenſive theatre, and his love of ſtudy made him ſolicitous of better means of inſtruction. Paris preſented both theſe advantages, and he accordingly repaired thither in 1764, at the age of nineteen, in ſearch of them.

Surgery at that period flouriſhed in the capital under the auſpices of a Lafaye, a Morand, an Andouillet, and a Louis. The ſight of ſuch great maſters excited the genius of thoſe who aſpired to emulate them: young Deſault deemed himſelf worthy of equalling men whom other ſtudents were content with only admiring. Animated by this ſentiment, he entirely reſigned himſelf to his ardour; anatomy became the ſpecial object of his labours, and his diſſections were not confined to the human body; for he inveſtigated by means of his knife, a prodigious number of animals of all kinds: at firſt, from a difficulty of procuring human ſubjects, and afterwards on account of the advantages which he experienced from this general method. In order to become intimately acquainted with our own organization, it is neceſſary to compare with it whatever has a reſemblance to it in other bodies.

He accordingly ſpent the greater part of the day in the amphitheatres. The hours ſtolen from his favourite labours were employed in attending the hoſpitals; he was the firſt at the bed of the patient where an operation was to be performed, and was ſure to be preſent at the dreſſings on purpoſe to examine the reſult. The infirmities of mankind, ſterile in reſpect to the vulgar, ſerved him as the beſt treatiſe for curing them; and the great ſurgeons of all nations have formed their mode of practice by contemplating the ſame book.

But he reckoned too much on a robuſt and vigorous temperament; for, after two years cloſe and aſſiduous application, he fell into a cachectical habit of body, which had nearly proved mortal, and which confined him for almoſt twelve months to his bed; but at length, owing partly to the vigour of his youth, and partly to the attention of his young friend Chopart, his inſeparable companion in his operations, who attended him alſo during his laſt illneſs, and only ſurvived him a few days, he was ſo fortunate as to recover.

Reſtored to life, he forgot that an exceſs of attention had conducted him to the very gates of death; a new career opened to his view, and required new efforts on his part. In the winter of 1766 he commenced a courſe of anatomy, and ſoon reckoned 300 pupils, moſt of them older than himſelf, who were attracted by the clearneſs of his demonſtrations, the methodical arrangement of his deſcriptions, and, above all, by his indefatigable zeal in the ſcience of inſtruction.

His ſucceſs inſpired the privileged profeſſors, whoſe ſchools became deſerted, with jealouſy and revenge; they employed the authority of the corporation againſt him, and would have nipped his efforts in the bud, had it not been for the protection of Louis and Lamartiniere, who were zealous of protecting a youth of talents, whoſe ſole reproach was that he had not wealth enough to purchaſe certain franchiſes, after all, had it not been for the permiſſion he obtained of borrowing the name of a celebrated phyſician, he muſt have actually deſiſted from his lectures.

Default's reputation now begun to be buzzed about, and a multitude of patients claimed his aſſiſtance; but he conſtantly refuſed to practiſe, until he ſhould be placed at the head of ſome great eſtabliſhment.

At length, at the repeated ſolicitations of his friends, he preſented himſelf as a candidate to the corporation of ſurgeons: and they, much to their honour, admitted him in 1776, on condition of paying the uſual fees when convenient. The following is the title of his theſis: "*De calculo veſicæ urinariæ, eoque extrahendo, prævia ſectione, ope inſtrumenti Haukenſiani emendati.*"

His public lectures were accompanied with as much celebrity as his private ones. Brilliant diſcoveries were not the object of his anatomical labours which were always connected with the art of healing: he was, however, the firſt man in France who taught ſurgical anatomy.

After becoming firſt a ſimple member, and then a counſellor, of the perpetual committee of the academy of ſurgery, he was appointed chief ſurgeon to the hoſpital of the college, and conſulting ſurgeon to that of St Sulpice: neither of theſe added any thing to his fortune, but they gave him a clear inſight into practice, and enabled him to judge of caſes by the inductions ariſing from his own experience.

In 1779 he invented the bandage now in uſe for fractures; by means of which, the fragments being kept in a ſtate of perpetual contact, become conſolidated, without the leaſt appearance of deformity, an almoſt inevitable conſequence of the former mode.

On his appointment to the place of ſurgeon major to the hoſpital *de la Charité*, in 1782, he introduced a new method of treatment in oblique fractures of the thigh bone; and he alſo healed, by means of a methodical compreſſion thoſe various ulcers whoſe cure had hitherto been attended with great difficulty. In addition to this, he ſubſtituted new bandages in fractures of the humerus and clavicle, and adopted a new mode of treating the hare-lip ſuperior to that uſed by Louis. He never recurred to amputation but in extreme caſes, when there was a certainty that diſſolution would have followed a neglect of the operation.

When a premature death carried off Ferrand, chief ſurgeon of the *Hotel-Dieu* in Paris, Default was conſidered as the moſt proper perſon to ſucceed him; and, on the demiſe of Moreau, the whole charge of the hoſpital devolved on him. After three years of ſolicitations and diſputes, he at length in 1788 proceeded in his long-projected ſcheme of eſtabliſhing a clinical ſchool; and a ſpacious amphitheatre was accordingly erected for that purpoſe. Scarcely had his firſt (A) courſe commenced, when the number of pupils who flocked around him was really aſtoniſhing. Foreigners repaired from all parts, and ſeveral of the neighbouring ſtates ſent ſtudents to Paris expreſsly for the purpoſe of aſſiſting at his demonſtrations. More than 600 auditors conſtantly attended, in order to learn a new ſyſtem, conſiſting of a ſimple mode of treatment diſengaged from ancient prejudices, and a complex incoherent practice.

A few of his improvements are here ſpecified.

1. The method of ligature employed by the ancients in the cure of umbilical hernias of children, having been generally omitted in the practice of the moderns, he again introduced and perfected this mode, and demonſtrated by his ſucceſs, its ſuperiority over compreſſive bandages.
2. He was one of the firſt men in France to extract the looſe cartilages *(cartilages flottans)* in joints.
3. He employed a new treatment, that of methodical compreſſion, in reſpect to ſchirroſities of the rectum; in order to which he introduced a candle or bougie, the ſize of which he gradually augmented.
4. He ſimplified, and rendered more commodious, the reduction of luxations of the humerus.
5. Fatal experience having pointed out the danger of employing the trepan in wounds of the head, he ſubſtituted another method of treatment *(l'uſage de l'émétique)* now adopted by many practitioners.
6. He made ſeveral very uſeful improvements on chirurgical inſtruments; ſuch as thoſe employed in the caſes

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(A) The buſineſs of the day was conducted in the following routine: 1. A public conſultation concerning the indigent out-patients. 2. The young practitioners belonging to the hoſpital read a detailed account of all the intereſting caſes of ſuch patients as were to be diſcharged that day. 3. The operations: each of theſe was preceded by a diſſertation on the ſtate of the patient, who was then carried to the amphitheatre, where Default, attended by his aſſiſtants, performed the operation in preſence of all the pupils. 4. Argumentative details, by the profeſſor, either on the dangerous maladies exiſting in the hoſpital, or on the ſituation of the patients on whom operations had been performed during the preceding day. 5. The diſection of ſubjects. And 6. A lecture on ſome particular branch of pathology.

caſes of polypus in the womb and noſtrils *(la pince à gaîne et des porte-nœuds pour la ligature des polypes*, &c.); for cutting through obſtructions in the different cavities*(le kiotome)*; and for the *fiſtula in ano.* In caſes of inciſion he introduced the uſe of the inſtrument *(le gorgeret)* invented by Marchetti, well known among foreigners, but almoſt totally neglected in France before this period.

He at the ſame time retrenched the uſe of a great number of ſuperfluous ones, and baniſhed all practices attended with greater pains than utility. Avoiding every thing that was complex, he proved that the art of healing, in imitation of nature, ought to be ſimple in its means, and fruitful in its reſources.

In 1791 he publiſhed his *Journal de Chirurgerie*, which was edited by his pupils, and deſtined to deſcribe the moſt intereſting occurrences in his ſchool, and alſo extracts from his lectures, which were then dedicated to the inveſtigation of the maladies incident to the urinary paſſages. The treatment of theſe diſeaſes, hitherto the reproach of practitioners, had been much improved by the aſſiſtance of the artiſt Bernard. The elaſtic probes *(les ſondes élaſtiques)*, on their firſt appearance, fixed the attention of all profeſſional men; but none knew better than Deſault how to appretiate their advantages. By means of them, he introduced a novel mode of cure in contractions of the urethra, which ſaved a great number of lives every year in the *Hotel-Dieu*. But he did not confine their uſe to the diſeaſes of the urethra alone, for he employed them to remove the divers obſtacles that impede deglutition or reſpiration.

In the midſt of ſuch a multiplicity of labours, and although he was obliged to attend 400 ſick twice a-day, Deſault nevertheleſs employed more than four hours of his time in viſiting private patients.

Few ſurgeons ever enjoyed ſuch an excluſive ſhare of public confidence; few ever poſſeſſed ſimilar means of enriching themſelves; and yet he neglected for a long time to take advantage of this.. Had he been leſs ardent for glory, he would have been more favoured by fortune; but he ſacrificed all intereſted views to the noble ambition of advancing his art. His clinical and anatomical courſes were gratuitouſly opened by him to the world after the year 1790; and while the public ſchools languiſhed in the midſt of troubles, inſeparable perhaps from a mighty revolution, he was forming the greater part of thoſe ſurgeons employed at this preſent moment in the numerous armies of the republic. Conſidered under this point of view alone, the ſervices which he rendered to humanity are incalculable: too happy if perſecution had not been his ſole reward!

While out of mere attachment to the public weal, he added to his various functions that of a member of the council of health, conferred on him in 1792 by the miniſter Servan, he was denounced in the popular ſocieties as an *egotiſt*, an *indifferent*, &c. and became one of the firſt victims of that proſcription which, under Robeſpierre, extended to nearly every man of talents.

Chaumette accuſed him to the ſections as having neglected the brave men wounded on the 10th of Auguſt, while they themſelves were laviſhing their bleſſings at the *Hotel-Dieu* on their ſaviour. Twice was he brought to the bar of a commune; deſirous of diſcovering a pretext for perſecution, the clamours of the people were unremittingly excited againſt him. He was at length carried away from his amphitheatre, while in the very act of haranguing his pupils; and, in conſequence of a *mandat d'arrêt* from the revolutionary committee, conducted by a body of armed men to the Luxembourg. From this horrid priſon few ever departed but to meet their fate; luckily, however, his name was not yet entered on that bloody liſt, in which thoſe of Maleſherbes and Lavoiſier were inſerted. On the contrary, at the end of three days he was liberated, and inſtantly reſumed all his functions.

On the eſtabliſhment of *L'Ecole de Santé*, Deſault was appointed clinical profeſſor; and for external, maladies he ſoon after obtained from the government the converſion of the *Evechè* into an hoſpital for ſurgical operations.

In the midſt of theſe plans, the troubles that occurred in the month of May unfortunately affected his mind, and made him dread leſt the days of proſcription ſhould return. It was in vain that his friends attempted to ſoothe his ſufferings; for on the night of the 29th of May, a malignant fever made its appearance, and a nearly continual delirium enſued until his death, which occurred on the 1ſt of June 1795, on which day he breathed his laſt, in the arms of his pupils, at the age of 51.

The populace were perſuaded that he was poiſoned. This ridiculous opinion originated in conſequence of the epoch of his death, which preceded but a ſhort time that of the ſon of Louis XVI. whom he had viſited during his illneſs in the priſon of the Temple. It is pretended that he fell a victim to his conſtant refuſal to yield to the criminal views entertained againſt the life of that child.

Deſault was of a middling ſtature. He was well proportioned, and poſſeſſed an open countenance. His temperament, naturally robuſt, had been fortified by his early education, and was never ſapped by an exceſs of pleaſures, for to them his heart was always indifferent. His ruling paſſion was the love of glory; his favourite purſuit, the practice and advancement of his art. He was warm, nay ſometimes violent; and his ſcholars were not always inclined to praiſe the ſweetneſs of his temper. On the other hand, his mind was noble, elevated, and great, even to exceſs.

The French Republic, eager to pay homage to his memory, has preſented his widow with a penſion of 2000 livres per annum. A ſon, Alexis Mathias Deſault, was the ſole fruit of his marriage; and he has left but one work behind him, in which the name of his friend Chopart is joined with his own. It is entitled *Traité des Maladies Chirurgicales et des Operations qui leur conviennent*, 2 vols 8vo.

DESEADA, *Deſirada* or *Deſiderada*, the firſt of the Caribbee iſlands, diſcovered by Columbus in his ſecond voyage, anno 1494, when he gave it that name. It is ſituated E. of Guadaloupe, and ſubject to the French; and is of little conſequence except in time of war, when it is the reſort of a number of privateers. It is 10 miles long and 5 broad, and looks at a diſtance like a galley, with a low point at the N. W. end. The Spaniards make this in their way to America, as well as Guadaloupe. N. lat. 16. 40. W. long. 61. 20.—*Morſe*.

DESEADA, or *Cape Deſire*, the ſouthern point of the

D'ETROIT, one of the principal towns, and beſt fortified, in the N. W. territory; ſituated on the weſtern bank of the ſtrait St Clair, or D'Etroit river between lake Erie and lake St Clair; 18 miles N. of the W. end of the former, and 9 miles below the latter. Fort D'Etroit is of an oblong figure, built with ſtockades, and advantageouſly ſituated, with one entire ſide commanding the river. It is near a mile in circumference, and encloſes about 300 wooden houſes and a Roman Catholic church; built in a regular manner, with parallel ſtreets, croſſing each other at right angles. Its ſituation is delightful, and in the centre of a pleaſant and fruitful country. For 8 miles below, and the ſame diſtance above Fort D'Etroit, on both ſides of the river, the country is divided into regular and well cultivated plantations; and from the contiguity of the farmers houſes to each other, they appear as two long extended villages. The inhabitants, who were moſtly French, were about 2000 in number in 1778, 500 of whom were as good markſmen as the Indians themſelves; and as well accuſtomed to the woods. They raiſe large ſtocks of black cattle, and great quantities of corn, which they grind by wind mills, and manufacture into excellent flour. The chief trade of D'Etroit conſiſts in a barter of coarſe European goods with the natives for furs, deer ſkins, tallow, &c.

By the treaty of Greenville, Aug. 3, 1795, the Indians have ceded to the United States the poſt of D'Etroit, and all the land to the N. the W. and the S. of it; of which the Indian title has been extinguiſhed by gifts or grants to the French or Engliſh governments, and ſo much more land is to be annexed to D'Etroit as ſhall be comprehended between Roſine river on the S.; lake St Clair on the N.; and a line the general courſe whereof ſhall be 6 miles from the W. end of lake Erie and D'Etroit river. The fort, &c. was delivered up by the Britiſh in July 1796, according to treaty. It lies 18 miles N. of lake Erie, 724 N. W. by W. from Philadelphia. N. lat. 42. 40. W. long. 82. 56.—*ib.*

D'Etroit *River*, or *Strait of St Clair*, flows from lake St Clair into the W. end of lake Erie, forming part of the boundary between the United States and Upper Canada. In aſcending it, its entrance is more than 3 miles wide, but it perceptibly diminiſhes; ſo that oppoſite the fort, 18 miles from lake Erie, it does not exceed half a mile in width; from thence to lake St Clair it widens to more than a mile. The channel of the ſtrait is gentle, and wide and deep enough for ſhipping of great burden, although it is incommoded by ſeveral iſlands, one of which is more than ſeven miles in length. Theſe iſlands are of a fertile ſoil, and from their ſituation afford a very agreeable appearance. The length of the river is 28 miles; and ſeveral ſtreams fall into it chiefly from the N. W. viz. Bauche, Clora, Curriere, D'Etroit, and Huron rivers.—*ib.*

DEVIL's *Mouth*, a name given by ſailors to a frightful volcano, near Leon Nicaraguay, in New-Spain, ſeated near the lake. N. lat. 13. 10. W. long. 65. 10.—*ib.*

Devil's *Noſe*, a promontory on the S. ſide of lake Ontario, 16 miles E. of Fiſhing bay, and 23 N. W. of the mouth of Geneſſee river.—*ib.*

Devil's *Iſland*, on the E. ſide of Cheſapeak bay, is in Somerſet co. Maryland, between Fiſhing bay and Nanokin river.—*ib.*

DEWAN, under the Mogul government, the receiver general and civic governor of a province: in private life a ſteward.

DEWANNY, the revenue department of a province.

DEWEE, an iſland in South-Carolina, which forms one of the three harbors of Charleſton city.—*Morſe.*

DIABETES Mellitus (ſee Medicine, n° 318, &c. *Encycl.*), is ſo formidable a diſeaſe, though not very frequent, that it would be unpardonable in us not to mention every method of treating it ſucceſsfully which has come to our knowledge. Since our article Medicine was publiſhed, Dr Rollo, ſurgeon general to the royal artillery, has ſuggeſted a method of treating this diſeaſe, which in various inſtances has been crowned with ſucceſs.

The Doctor ſuppoſes, that in this complaint the vegetable matter taken into the ſtomach has not, from ſome defect in this organ, undergone a ſufficient change to form proper chyle: that in conſequence of this, much ſaccharine matter is evolved, which, when carried into the circulation, proves a general ſtimulus, producing head-aches and quickneſs of pulſe, but that it acts more remarkably on the kidneys, occaſioning a conſtant and copious ſecretion of ſweet urine. From this hypotheſis he was naturally led to adopt a plan of cure, which has proved completely ſucceſsful. The indication he lays down are: 1. To prevent the formation of ſaccharine matter in the ſtomach; and, 2. To remove the morbidly increaſed action of this organ, and reſtore it to a healthful condition. Theſe indications are to be anſwered by a complete diet of animal food, and by the uſe of ſuch medicines as ſhall diminiſh the action of the ſtomach, and at the ſame time counteract the formation of ſaccharine matter. The remedies employed for this purpoſe have been emetics, kali ſulphuratum, lime-water, hepatized ammonia, and vegetable narcotics. But the principal dependence is to be placed on a total abſtinence from all vegetable matter, which alone can ſupply the ſaccharine principle. By a regular perſeverance in this plan, the firſt of two patients was completely cured in four weeks, although the diſeaſe had been of ſeven months continuance. The urine, which at the commencement of the treatment was ſweet, and amounted to 24 pints daily, was at laſt reduced to 1½ pint, being at the ſame time free from any ſaccharine impregnation. The ſecond patient, from his age and other circumſtances, although relieved from the diabetic affection, did not regain his wonted ſtate of health; but even in this caſe, the effects produced by the treatment, when properly attended to, were moſt decidedly in confirmation of this plan of cure.

The Doctor has received ſeveral communications in conſequence of the diſperſion of the printed notes on the firſt caſe. The moſt important are the reſult of two caſes treated in this way by Dr Cleghorn of Glaſgow, and one by Drs Currie and Gerard at Liverpool; all of which afford the ſtrongeſt corroboration of the efficacy of this mode of treatment.

DIAMOND, the moſt precious of all the gems; for the nature of which ſee Chemistry, n° 33, &c. in this *Supplement*.

DICK's *River* in Kentucky, is a branch of Kentucky river which it joins in a N. W. direction. It is about 50 miles long, and 45 yards wide at the mouth, and has a number of excellent mill ſeats, and runs through a body of firſt rate land.—*Morse.*

DIDEROT (Dionyſius) of the academy of Berlin, the ſon of a cutler, was born at Langres in 1713. The Jeſuits, with whom he went through a courſe of ſtudy, were deſirous of having him in their order; and one of his uncles, deſigning him for a canonry which he had in his gift, prevailed upon him to take the tonſure.

His father ſeems to have known him better; for perceiving that he was not inclined to be a Jeſuit, nor fit to be a canon, he ſent him to Paris to proſecute the ſtudy of the law. To the law, however, he paid very little attention, but devoted his time to ſcience and general literature; which ſo offended his father, that he ſtopped the remittance of his pecuniary allowance, and ſeemed for ſome time to have abandoned him.

The talents of young Diderot ſupplied him with a maintenance, and drew him from obſcurity. According to his friends, his capacious mind embraced phyſics, geometry, metaphyſics, ethics, and the belles lettres, from the time that he began to read with reflection; and it is certain that he aſpired at being a maſter in all theſe departments of literature. His bold and elevated imagination ſeemed to give him likewiſe a turn for poetry; but he neglected it for the ſciences. He ſettled at an early period at Paris, where the natural eloquence which animated his converſation procured him friends and patrons. What firſt drew the attention of the public to him as an author, and gave him a high reputation among a certain claſs of readers, was a ſmall volume written againſt the Chriſtian religion, and intitled *Penſées Philoſophiques;* which was reprinted afterwards under the title of *Etrennes aux Eſprits-forts.*

This book appeared in 1746, 12mo. The adepts of the new philoſophy compared it, for perſpicuity, elegance, and force of diction, to the *Penſées de Paſcal.* But the aim of the two authors was widely different; Paſcal employed his talents and his erudition, which was profound and various, to ſupport and illuſtrate the great truths of our holy religion, which Diderot attacked by all the diſingenuous arts of an unprincipled ſophiſt. The *Penſées Philoſophiques,* however, became popular. It contributed to promote the object of that conſpiracy which had been for ſome time formed againſt every thing which ennobles human nature (ſee JACOBINS in this *Supplement).* It was therefore applauded by Voltaire and D'Alembert, and read, of courſe, by every man and woman of taſte in Paris.

Our author was more uſually employed in 1746, when, together with Meſſrs *Eidous* and *Touiſſant,* he publiſhed a general Dictionary of Medicine, in ſix volumes folio. This work, it muſt be confeſſed, has conſiderable merit; for though there are in it ſeveral articles ſuperficial and erroneous, there are many others or ſuch deep and accurate diſquiſition, as deſervedly recommend it to men of ſcience.

It was about this time that an intimacy was formed between Diderot and D'Alembert, and that, under the direction of Voltaire, they formed the idea of a *Dictionaire Encyclopedique.* The great objects which they had in view when they entered upon this work are now univerſally known. D'Alembert was a profound mathematician, Diderot had conſiderable knowledge in the phyſical ſciences, more eſpecially mechanical philoſophy, and Voltaire was a maſter of the belles lettres.

It is not to be ſuppoſed that ſuch men would publiſh any thing very defective in theſe departments of ſcience; but an *Encyclopedie* muſt treat of *religion;* and to every kind of religion they were all ſworn enemies. They engaged, however, a very worthy, though not very acute, clergyman, to furniſh the theological articles; and for other branches of knowledge, they were promiſed the aſſiſtance of ſeveral men of letters, and of a variety of artiſts.

Diderot took upon himſelf the deſcription of arts and trades; one of the moſt important departments of the work, and the moſt acceptable to the public. To the particulars of the ſeveral proceſſes of the workmen he ſometimes added reflections, ſpeculations, and principles, adapted to their elucidation. But beſides his own department, he furniſhed articles on almoſt every other ſubject.

By thoſe who knew not the great aim of the undertakers of this work, it has been regretted that Diderot was not leſs verboſe, leſs of the diſſertator, and leſs inclined to digreſſions. He has alſo been cenſured for employing needleſsly a ſcientific language, and for having recourſe to metaphyſical doctrines, frequently unintelligible, which occaſioned him to be called the *Lycophron of philoſophy;* for having introduced a number of definitions incapable of enlightening the ignorant, and which the philoſopher ſeems to have invented for no other purpoſe than to have it thought that he had great conceptions; while, in fact, he had not the art of expreſſing perſpicuouſly and ſimply the ideas of others. But theſe complaints ariſe from miſtaking entirely the purpoſe for which he wrote.

It has been completely proved, that one great object for which the philoſophers, as they called themſelves, undertook the compilation of the *Encyclopedie* was to ſap the foundation of all religion. This was to be attempted, not directly and avowedly; for bare-faced atheiſm would not then have been ſuffered in France. A cloak, therefore, was to be worn, and the poiſoned dagger to be concealed under it. Whilſt the well meaning divine was ſupporting, by the beſt arguments which he could deviſe, the religion of his country, Diderot and D'Alembert were overturning thoſe arguments under titles which properly allowed of no ſuch diſquiſitions. This neceſſarily produced digreſſions; for the greateſt genius on earth could not, when writing on the laws of motion, attack the myſteries of Chriſtianity without wandering from his ſubject: but that the object of theſe digreſſions might not paſs unnoticed by *any* claſs of readers, care was taken to refer to them from the articles where the queſtion was diſcuſſed by the divine. That when employed in this way, Diderot ſeems to write obſcurely, is indeed true; but the obſcurity is not his. His atheiſm was ſo plain, that for the moſt part D'Alembert, or ſome other leader of the gang, had to retouch his articles, and throw a miſt over them, to render their intention the leſs obvious.

Even with all this care and ſtudied obſcurity, the deſign of the *Encyclopedie* was too palpable not to be ſeen, and too wicked not to give offence. Certain wild poſitions on government and on religion occaſioned the impreſſion to be ſuſpended in 1752. At that time there were no more than two volumes of the dictionary publiſhed; and the prohibition of the ſucceeding ones was only taken off at the end of 1753. Five new volumes then ſucceſſively appeared. But in 1757 a new ſtorm aroſe, and the book was ſuppreſſed. The remainder did not appear till about ten years after; and was then for a while only privately diſtributed; ſome copies having been ſeized by government, and the printers ſhut up in the baſtile. The merit, however, of ſome of the articles is confeſſedly great; and the firſt edition was quickly ſold off.

Thus was this great work in the preſs from 1751 to 1767; during which period, Diderot and D'Alembert were accuſtomed to frequent the coffee-houſes of Paris, and to enter with keenneſs into religious diſputes: the former attacking Chriſtianity; and the latter, under the maſk of piety, defending it; but always yielding to the arguments of his opponent. This practice was put a ſtop to by the police; and Diderot, when reproached by the lieutenant with preaching atheiſm, replied, "Cela eſt vrai, je ſuis athée, & m'en fai gloire."

Finding his impious converſations interrupted, and the publication of the *Encyclopedie* rendered tedious by the vigilance of government, he thought of propagating his notions by other vehicles. Alternately ſerious and ſportive, ſolid and frivolous, he publiſhed, at the very time he was working on the Dictionary of Sciences, ſeveral productions, which could ſcarcely have been expected from a man ſo completely employed. His *Bijoux Indiſcrets*, 2 vols 12mo, are of this number—a diſguſting work, even to thoſe young people who are unhappily too eager for following after licentious romances. Even here a certain philoſophical pedantry appears in the very paſſages where it is moſt miſplaced, and never is the author more aukward than where he intends to diſplay a graceful eaſe.

The *Fils Naturel*, and the *Pere de Famille*, two comedies in proſe, which appeared in 1757 and 1758, are not of the ſame kind with the *Bijoux Indiſcrets*. They are moral and affecting dramas, where we ſee at once a nervous ſtyle and pathetic ſentiments. The former piece is a picture of the trials of virtue, a conflict between intereſts and paſſions, wherein love and friendſhip play important parts. It has been ſaid, that Diderot borrowed it from Goldoni: but if that be the caſe, the copy does honour to the original; and, with the exception of a ſmall number of ſcenes, where the author mixes his philoſophical jargon with the ſentiments of the heart, and ſome ſentences out of place, the ſtyle is affecting and natural enough. In the ſecond comedy, a tender, virtuous, and humane father appears, whoſe tranquillity is diſturbed by the parential ſolicitudes, inſpired by the lively and impetuous paſſions of his children. This philoſophical, moral, and almoſt tragical comedy, has produced conſiderable effects on ſeveral theatres of Europe. The dedication, to the princeſs of Naſſau Saarbuck, is a little moral tract of a ſingular turn, without deviating from nature. This piece, written with a true dignity of ſtyle, proves that the author poſſeſſed a great fund of moral ſentiments and philoſophical ideas. At the end of theſe two pieces, publiſhed together under the title of *Theatre de M. Diderot*, are dialogues, containing profound reflections and novel views of the dramatic art. In his plays he has endeavoured to unite the characters of Ariſtophanes and Plato; and in his reflections he ſometimes diſplays the genius of Ariſtotle.

This ſpirit of criticiſm is exhibited, but with too much licence, in two other works, which made a great noiſe. The former appeared in 1749, 12mo. intitled *Letters on the Blind for the Uſe of thoſe who See.* The free notions of the author in this work coſt him his liberty. He underwent a ſix months impriſonment at Viorcennes. Having naturally ſtrong paſſions and a haughty ſpirit, and finding himſelf on a ſudden deprived of liberty and of all intercourſe with human beings, he was threatened with the loſs of his reaſon. The danger was great; and to prevent it, they were obliged to allow him to leave his room, to take frequent walks, and to receive the viſits of a few literary men; among whom J. J. Rouſſeau, at that time his friend, went and adminiſtered conſolation to him, which he ought not to have forgotten.

The letter on the Blind was followed by another *On the Deaf and Dumb, for the Uſe of thoſe who can Hear and Speak;* 1751, 2 vols, 12mo. Under this title the author delivered reflections on metaphyſics, on poetry, on eloquence, on muſic, &c. In this eſſay there are ſome good things, among others abſurd and imperfect. Though he ſtrives to be perſpicuous, yet he is not always underſtood; and this is more his fault than that of his readers. Of what he has compoſed on abſtract ſubjects, it has been ſaid that it is a chaos on which the light ſhines only at intervals. The other productions of Diderot betray the ſame defect of clearneſs and preciſion, and the ſame uncouth emphaſis, for which he has always been blamed.

The principal of them are, 1. Principles of Moral Philoſophy, 1745, 12mo; of which the Abbé de Fontaine ſpeaks well, though it met with no great ſucceſs. It was our philoſopher's fate to write a great deal, and not to leave a good book, or at leaſt a book well compoſed. 2. Hiſtory of Greece, tranſlated from the Engliſh of Stanyan, 3 vols, 12mo; an indifferent tranſlation of an indifferent book. 3. Pieces on ſeveral Mathematical Subjects, 1748, 8vo. 4. Reflections on the Interpretation of Nature, 1754, 12mo. This interpreter is very obſcure. 5. The Code of Nature, 1755, 12mo; which is certainly not the code of Chriſtianity. 6. The Sixth Senſe, 1752, 12mo. 7. Of public Education; one of that ſwarm of publications produced by the appearance of Emilius, and the abolition of the Jeſuits. Though all the ideas of this author could not be adopted, yet ſome of them are very judicious, and would be highly uſeful in the execution. 8. Panegyric on Richardſon. Full of nerve and animation. 9. Life of Seneca. This is the laſt work which he acknowledged; and it is one of thoſe by Diderot that is peruſed with moſt pleaſure, even in rectifying the judgments he paſſes on Seneca and other celebrated men. The Abbé Barruel ſays, that he was the author of *Syſteme de la Nature*, which is uſually given to Robinet; and it is certain, that if he was not the author, he furniſhed hints, and reviſed the whole. Yet the junto of atheiſts were themſelves aſhamed of the firſt edition of that work; and after all Diderot's care to improve it, the ſubſequent editions are, notwithſtanding his boaſted knowledge of the laws of nature, contemptible in the eyes of a real mechanical philoſopher.

When a new edition of the *Encyclopedie* was reſolved on, Diderot, the editor of the former edition, thus addreſſes the bookſellers who had undertaken to republiſh it. "The imperfections (ſays he) of this work originated in a great variety of cauſes. We had not time to be very ſcrupulous in the choice of our coadjutors. Among ſome excellent perſons, there were others weak, indifferent, and altogether bad. Hence that motley appearance of the work, where we ſee the rude attempt of the ſchool-boy by the ſide of a piece from the hand of a maſter; a piece of nonſenſe next neighbour to a ſublime performance; ſome working for no pay, ſoon loſt their firſt fervour; others, badly recompenſed, ſerved us accordingly. The *Encyclopedie* was a gulph into which all kinds of ſcribblers promiſcuouſly threw their contributions; their pieces ill conceived, and worſe digeſted, good, bad, contemptible, true, falſe, uncertain, and always incoherent and unequal; the reference, that belonged to the very parts aſſigned to a perſon, never filled up by him. A refutation is often found where we ſhould naturally expect a proof. There was no exact correſpondence between the text and the plates. To remedy this defect, recourſe was had to long explications. But how many unintelligible machines, for want of letters to denote the plates!" To this confeſſion Diderot added particular details on various parts; ſuch as proved that there were in the *Encyclopedie* ſubjects to be not only retouched, but to be compoſed afreſh: and this was what a new company of literati and artiſts ſet themſelves to work upon in the *Encyclopedie Methodique*.

This immenſe work is not yet completed; and therefore we cannot ſpeak of it as a whole; but it it is ſurely not leſs verboſe than the former edition, nor do the aims of its editors appear to be purer. That it contains much valuable information in chemiſtry, and indeed in every department of phyſical ſcience, no candid man will controvert: but its articles on abſtract philoſophy are prolix and obſcure; and it betrays the ſame impiety, the ſame eager deſire to corrupt the principles of the riſing generation, and the ſame contempt for every thing which can make mankind happy here or hereafter, with the former edition.

Notwithſtanding his numerous publications, Diderot was never rich. Soon after the publication of the laſt volumes of the *Encyclopedie*, upon which he had been employed for upwards of twenty years, his circumſtances were ſo ſtraitened, that an expedient was to be deviſed for their improvement. He had long correſponded with the late Empreſs of Ruſſia, whom he perſuaded to conſider him as the greateſt, or *one* of the greateſt economiſts in France. In the courſe of the correſpondence he had mentioned his own library as one of the moſt valuable in Europe; and when Catharine wanted to purchaſe it and make him librarian, he ſaid that his conſtitution could not ſupport the cold climate of St Peterſburg. She offered to let him keep it during his lifetime in Paris; and the library was ſold for an immenſe price. When her ambaſſador wanted to ſee it, after a year or two's payments, and the viſitation could be no longer put off, Diderot was obliged to run in a hurry through all the bookſellers ſhops in Germany to fill his empty ſhelves with old volumes. He had the good fortune to ſave appearances; but the trick took air, becauſe he had been niggardly in his attention to the ambaſſador's ſecretary. This, however, did not hinder him from viſiting his imperial pupil, to whom he told a poor ſtory, in hopes of getting his daughter married with parade, and patronized by her majeſty; but it was ſeen through, and he was diſappointed.

In the year 1784 Diderot's health began viſibly to decline, and one of his domeſtics, perceiving that his death was at no great diſtance, acquainted him with his apprehenſions, and addreſſed him on the importance of preparing for another world. He heard the man with attention, thanked him kindly, acknowledged that his ſituation required ſeriouſneſs, and promiſed to weigh well what he had ſaid. Some time after this converſation he deſired that a prieſt might be brought; and the ſame domeſtic introduced to him M. de Farſac, Curé de St Sulpice. Diderot ſaw this eccleſiaſtic ſeveral times, and was preparing to make a public recantation of his errors. Condorcet and the other adepts now crowded about him, perſuaded him that he was cheated, that his caſe was not ſo dangerous as it was ſaid to be, and that he only wanted the country air to reſtore him to health. For ſome time he reſiſted their attempts to bring him back to atheiſm, but was at laſt prevailed upon to try the effect of the country air. His departure was kept ſecret, and he was concealed in the country till the 2d of July, when he died. His dead body was ſecretly brought back to Paris, and a report was ſpread and believed, that he died ſuddenly on riſing from the table, without remorſe, and with his atheiſm unſhaken.

To draw a formal character of this wretch is ſurely ſuperfluous. His friends extol his frankneſs, his diſintereſtedneſs, and his integrity; but except his groſs avowal of atheiſm, which may in France be called frankneſs, this character is belied by every tranſaction of his life. He married, and had a daughter, as has been already mentioned. M. Bauzé, referred to by Abbé Barruel, coming one day into Diderot's houſe, found him explaining to this daughter a chapter of the goſpel. When he expreſſed ſome ſurpriſe at this conduct, Diderot ſaid: "J'entends ce que vous voulez dire; mais au fond, quelles meilleures leçons pourrois-je lui donner, ou trouverai-je mieux?" It was a common aſſertion of Diderot's, that between him and his dog "il n'y avoit de difference que habit." In uttering this ſentiment, he reſembled not Pope's Indian with untutored mind,

> "Who thinks, admitted to that equal ſky,
> "His faithful dog ſhall bear him company."

The Indian hopes to carry his dog with him to heaven; but Diderot hoped to die like a dog, and to be as if he had never been.

DIFFERENTIAL METHOD, is the art of working with the differences of quantities. By this method any term of a ſeries may be found from the ſeveral orders of differences being given; or *vice verſa*, any difference may be found from having the terms of the ſeries given: it likewiſe ſhews how to find the ſum of ſuch a ſeries. And it gives rules to find by interpolation any intermediate term, which is not expreſſed in the ſeries, by having its place or poſition given.

When any ſeries of quantities is propoſed, take the firſt term from the ſecond, the ſecond from the third, the third from the fourth, &c. then all theſe remainders make a new ſeries, called the *firſt order of differences*. In this new ſeries take the firſt term from the ſecond, the ſecond from the third, the third from the fourth, &c. as before; and theſe remainders make another ſeries, called the *ſecond order of differences*. In like manner, in this ſeries, take the firſt term from the ſecond, the

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ſecond from the third, &c.; and theſe will make a ſeries called the *third order of differences;* and after this manner you may proceed as far as you will. Thus in the following propoſition A, *b*, *c*, *d*, *e*, &c. is the ſeries; B, B^2, B^3, B^4, &c. the firſt order of differences; C, C^2, C^3, &c. the ſecond order of differences; D, D^2, &c. the third order; E, &c. the fourth order, and ſo on. But the firſt terms of theſe ſeveral orders of differences, as B, C, D, E, &c. are thoſe that are principally made uſe of in calculations by this method.

Prop. I. If there be any ſeries, A, *b*, *c*, *d*, *e*, &c. and if there be taken the firſt differences B, B^2, B^3, &c. the ſecond differences C, C^2, C^3, &c. the third differences D, D^2, D^3, &c. and ſo on.

Then if T ſtand for the firſt term of the *n*th differences, $\pm T = A - nb + n \times \frac{n-1}{2} c - n \times \frac{n-1}{2} \times \frac{n-2}{3} d + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} e - \&c.$ that is, + T, when *n* is even, and — T when *n* is odd.

The ſeveral orders of differences being taken as before directed, will ſtand thus. Then,

$$\begin{array}{ccccc} A & & & & \\ & B & & & \\ b & & C & & \\ & & & D & \\ & B^2 & & & E \\ c & & C^2 & & \\ & & & D^2 & \\ & B^3 & & & \\ d & & C^3 & & \\ & B^4 & & \&c. & \\ e & & & & \end{array}$$

ſeries A, *b*, *c*, *d*, *e*, &c.
1ſt diff. $b-A$, $c-b$, $d-c$, $e-d$, &c.
2d diff. $c-2b+A$, $d-2c+b$, $e-2d+c$, &c.
3d diff. $d-3c+3b-A$, $e-3d+3c-b$, &c.
4th diff. $e-4d+6c-4b+A$, &c.

That is, $B = b - A$, $C = c - 2b + A$, $D = d - 3c + 3b - A$, $E = e - 4d + 6c - 4b + A$, &c. or $-B = A - b$, $+C = A - 2b + c$, $-D = A - 3b + 3c - d$, $+E = A - 4b + 6c - 4d + e$, &c. where, putting T ſucceſſively equal to B, C, D, E, &c. and $n = 1, 2, 3, 4$, &c. the prop. will be evident.

Cor. Hence
$A = A$, the firſt term.
$B = -A + b$, the firſt difference.
$C = A - 2b + c$, the 2d difference.
$D = -A + 3b - 3c + d$, the 3d difference.
$E = A - 4b + 6c - 4d + e$, the 4th difference.
$F = -A + 5b - 10c + 10d - 5e + f$, the 5th difference, &c.

Prop. II. If A, *b*, *c*, *d*, *e*, &c. be any ſeries, and there be taken B, C, D, E, &c. the firſt of the ſeveral orders of differences;

Then, the *n*th term of the ſeries will be $= A + \frac{n-1}{1} B + \frac{n-1}{1} \times \frac{n-2}{2} C + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} D + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} E +$, &c.

For from the equations in the laſt Prop. viz. $B = b - A$, $C = c - 2b + A$, &c. we have, by tranſpoſing, $b = A + B$, $= -A + 2b + C = -A + 2A + 2B + C$ (expunging *b*); that is,
$c = A + 2B + C$, $d = A - 3b + 3c + D = A - 3A - 3B + 3A + 6B + 3C + D$ (expunging *b* and *c*); that is, $d = A + 3B + 3C + D$. Alſo $e = -A + 4b - 6c - 4d + E =$ (expunging *b*, *c*, *d*,) $-A + 4A + 4B - 6A - 12B - 6C + 4A + 12B + 12C + 4D + E$; that is $e = A + 4B + 6C + 4D + E$, &c.

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Then putting A, *b*, *c*, *d*, &c. for the *n*th term, and *n* ſucceſſively $= 1, 2, 3, 4$, &c. the ſeries will be evident.

Cor. 1. If d', d'', d''', &c. be the firſt of the firſt, ſecond, third order, &c. of differences; then

The *n*th term of the ſeries A, *b*, *c*, *d*, &c. will be $= A + \frac{n-1}{1} d' + \frac{n-1}{1} \times \frac{n-2}{2} d'' + \frac{n-1}{1} \times \frac{n-2}{2} + \frac{n-3}{3} d''' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4} d'''' +$ &c.

For $B = d'$, $C = d''$, $D = \underline{d'''}$, &c. And the coefficients are the unciæ of the $\overline{n-1}$th power.

Cor. 2. Hence alſo it follows, that any term of a given ſeries may be accurately determined, if the differences of any order happen at laſt to be equal.

Cor. 3 Hence
$A = A$, the firſt term.
$b = A + B$, the 2d term.
$c = A + 2B + C$, the 3d term.
$d = A + 3B + 3C + D$, the 4th term.
$e = A + 4B + 6C + 4D + E$, the 5th term.
$f = A + 5B + 10C + 10D + 5E + F$, the 6th term.
$g = A + 6B + 15C + 20D + 15E + 6F + G$, the 7th term, &c.

Prop. III. If *a*, *b*, *c*, *d*, *e*, &c. be any ſeries, and d' d'', d''', &c. the firſt of the ſeveral orders of differences; then

The ſum of *n* terms of the ſeries is $= na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} d''' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} \times \frac{n-4}{5} d'''' +$, &c.

For in the ſeries of quantities,
o, a, $a+b$, $a+b+c$, $a+b+c+d$, &c.
1ſt diff. are a, b, c, d, &c.
2d dff. d', $d'2$, $d'3$, &c.
3d diff. d'', $d''2$, &c.
4th diff. d''', &c.

Therefore (by Cor. 1. Prop. II.) the $\overline{n+1}$th term of the ſeries o, a, $a+b$, $a+b+c$, $a+b+c+d$, &c. or the *n*th term of the ſeries, a, $a+b$, a, $+b+c$, $a+b+c+d$, &c. is $= o + na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' +$ &c. But the *n*th term of the ſeries a, $a+b$, $a+b+c$, &c. is the ſum of *n* terms of the ſeries, *a*, *b*, *c*, *d*, &c. and therefore equal to $na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' +$ &c.

For a fuller account of this method and its application to curves, we refer the reader to Emerſon's works, from which theſe three propoſitions are taken.

DIFFRACTION, a term firſt uſed by Grimaldi, to denote that property of the rays of light, which others have called inflection; the diſcovery of which is attributed by ſome to Grimaldi, and by others to Dr Hook.

DIGBY, ſituated on the S. E. ſide of Annapolis bay, 18 miles S. W. of Annapolis, and 53 N. by E.

of Yarmouth, is one of the moſt conſiderable of the new ſettlements in Nova-Scotia.—*Morſe.*

DIGGES (Leonard), an eminent mathematician of the 16th century, was deſcended from an ancient family, and born at Digges-court, in the pariſh of Barham in Kent; but we know not in what year. He was ſent to Univerſity-college in Oxford, where he laid a good foundation of learning and ſcience, and retiring thence without a degree, proſecuted his ſtudies, and compoſed the following works: 1. "Tectonicum: briefly ſhewing the exact Meaſuring, and ſpeedy Reckoning of all manner of Lands, Squares, Timber, Stones, Steeples, &c. 1556," 4to. Augmented and publiſhed again by his ſon Thomas Digges, 1592, 4to, and reprinted in 1647, 4to. 2. "A geometrical practical Treatiſe, named *Pantometria*, in three books." This he left in manuſcript; but after his death his ſon ſupplied ſuch parts of it as were obſcure and imperfect, and publiſhed it in 1591, folio; ſubjoining, "A Diſcourſe geometrical of the five regular and platonical bodies, containing ſundry theoretical and practical propoſitions, ariſing by mutual conference of theſe ſolids, inſcription, circumſpection, and transformation." 3. "Prognoſtication everlaſting of right good Effect: or, Choice Rules to judge the Weather by the Sun, Moon, and Stars, &c." 1555, 1556, and 1564, 4to, corrected and augmented by his ſon, with divers general tables, and many compendious rules, 1592, 4to. He died about 1574.

Digges (Thomas), only ſon of Leonard Digges, after a liberal ſchool education, went and ſtudied for ſome time at Oxford; and by the improvements which he made there, and the inſtructions of his learned father, became one of the greateſt mathematicians of his age. When Queen Elizabeth ſent ſome forces to aſſiſt the oppreſſed inhabitants of the Netherlands, Digges was appointed muſter maſter-general of them; by which he had an opportunity of becoming ſkilled in the art of war. Beſides reviſing, correcting, and enlarging ſome pieces of his father's already mentioned, he wrote and publiſhed the following learned works himſelf, namely, 1. "*Alæ ſive ſcalæ Mathematicæ*; or, Mathematical Wings or Ladders, 1573," 4to. This book contains ſeveral demonſtrations for finding the parallaxes of any comet or other celeſtial body, with a correction of the errors in the uſe of the *radius aſtronomicus*. 2. "An arithmetical military Treatiſe, containing ſo much of Arithmetic as is neceſſary towards military Diſcipline, 1579," 4to. 3. "A geometrical Treatiſe, named *Stratioticos*, requiſite for the perfection of ſoldiers, 1579," 4to. This was begun by his father, but finiſhed by himſelf. They were both reprinted together in 1590, with ſeveral amendments and additions under this title, "An arithmetical warlike Treatiſe, named *Stratioticos*, compendiouſly teaching the ſcience of numbers, as well in fractions as integers, and ſo much of the rules and equations algebraical, and art of numbers coeffical, as are requiſite for the profeſſion of a ſouldier. Together with the moderne militarie diſcipline, offices, lawes, and orders in every well-governed campe and armie, inviolably to be obſerved." At the end of this work there are two pieces; the firſt intitled, "A briefe and true report of the proceedings of the Earle of Leyceſter, for the reliefe of the towne of Sluce, from his arrival at Vliſhing, about the end of June 1587, untill the ſurrendrie thereof 26 Julii next enſuing. Whereby it ſhall plainelie appear, his Excellencie was not in anie fault for the loſſe of that towne"—The ſecond, "A briefe diſcourſe what orders were beſt for repulſing of foraine forces, if at any time they ſhould invade us by ſea in Kent, or elſewhere." 4. "A perfect deſcription of the celeſtial orbs, according to the moſt ancient doctrine of the Pythagoreans, &c." This was placed at the end of his father's "Prognoſtication everlaſting, &c." printed in 1592, 4to. 5. "A humble motive for aſſociation to maintain the religion eſtabliſhed, 1601," 8vo. To which is added, his "Letter to the ſame purpoſe to the Archbiſhops and Biſhops of England." 6. "England's Defence: or, a Treatiſe concerning Invaſion." This is a tract of the ſame nature with that printed at the end of his *Stratioticos*, and called, "A briefe Diſcourſe, &c." It was written in 1599, but not publiſhed till 1686. 7. "A Letter printed before Dr John Dee's *Parallaticæ Commentationis praxeoſque nucleus quidam*, 1573," 4to. Beſides theſe and his *Nova Corpora*, he had by him ſeveral mathematical treatiſes ready for the preſs; which, by reaſon of law-ſuits and other avocations he was hindered from publiſhing. He died in 1595, but we know not at what age.

DIGHTON, a poſt town in Briſtol co. Maſſachuſetts, 7 miles from Taunton, and 20 from Warren, in Rhode-Iſland. There are 236 houſes in the townſhip, and 1793 inhabitants.—*Morſe.*

DIMINUTION, in muſic, is the abating ſomething of the full value or quantity of any note.

DINWIDDIE, a co. in Virginia, S. of Appamattox river, which divides it from Cheſterfield. It is about 30 miles long, and 20 broad, and its chief town is Peterſburg.—*Morſe.*

DIOPHANTUS, a celebrated mathematician of Alexandria, has been reputed to be the inventor of algebra; at leaſt his is the earlieſt work extant on that ſcience. It is not certain when Diophantus lived. Some have placed him before Chriſt, and ſome after, in the reigns of Nero and the Antonines; but all with equal uncertainty. It ſeems he is the ſame Diophantus who wrote the Canon Aſtronomicus, which Suidas ſays was commented on by the celebrated Hypatia, daughter of Theon of Alexandria. His reputation muſt have been very high among the ancients, ſince they ranked him with Pythagoras and Euclid in mathematical learning. Bachet in his notes upon the 5th book De Arithmeticis, has collected, from Diophantus's epitaph in the Anthologia, the following circumſtances of his life, namely, that he was married when he was 33 years old, and had a ſon born five years after; that this ſon died when he was 42 years of age, and that his father did not ſurvive him above four years; from which it appears that Diophantus was 84 years old when he died.

DIOPTER or Dioptra, the ſame with the index or alhidade of an aſtrolabe or other ſuch inſtrument.

Dioptra was an inſtrument invented by Hipparchus, which ſerved for ſeveral uſes; as, to level water-courſes; to take the height of towers, or places at a diſtance; to determine the places, magnitudes, and diſtances of the planets, &c.

DIRECT, in arithmetic, is when the proportion of any terms, or quantities, is in the natural or direct order in which they ſtand; being the oppoſite to inverſe, which conſiders the proportion in the inverted order of the terms. So, 3 : 4 : : 6 : 8 directly ; or 3 : 4 : : 8 : 6 inverſely.

DIRECTION, in Aſtronomy, the motion and other phenomena of a planet when direct.

Direction, in aſtrology, is a kind of calculus, by which they pretend to find the time in which any notable accident ſhall befal the perſon whoſe horoſcope is drawn.

DISCRETE Quantity, is ſuch as is not continued and joined together. Such, for inſtance, is any number.

DISMAL, a ſwamp in the townſhip of Milton, Lincoln co. diſtrict of Maine.—*Morſe.*

Dismal *Swamp*, called the *Great Diſmal*, to diſtinguiſh it from another ſwamp called Diſmal, in Curri-tuck co. is a very large bog extending from N. to S. near 30 miles, and from E. to W. at a medium about 10 miles: partly in Virginia, and partly in North-Carolina. No leſs than 5 navigable rivers, beſides creeks, riſe out of it; whereof two run into Virginia, viz. the S. branch of Elizabeth, and the S. branch of Nanſemond river, and 3 into North-Carolina, namely, North river, North-Weſt river and Perquimons. All theſe hide their heads, properly ſpeaking, in the Diſmal, there being no ſigns of them above ground. For this reaſon there muſt be plentiful ſubterraneous ſtores of water to feed ſo many rivers, or elſe the ſoil is ſo replete with this element, drained from the highlands that ſurround it, that it can abundantly afford theſe ſupplies. This is moſt probable, as the ground of the ſwamp is a mere quagmire, trembling under the feet of thoſe that walk upon it, and every impreſſion is inſtantly filled with water. The ſkirts of the ſwamp, towards the E. are overgrown with reeds, 10 or 12 feet high, interſperſed every where with ſtrong bamboo briers. Among theſe grow here and there a cypreſs or white cedar, which laſt is commonly miſtaken for the juniper. Towards the S. end of it is a large tract of reeds, which being conſtantly green, and waving in the wind, is called the green ſea. In many parts, eſpecially on the borders, grows an ever green ſhrub, very plentifully, called the gall buſh. It bears a berry which dies a black color like the gall of an oak, whence it has its name. Near the middle of the Diſmal the trees grow much thicker, both cypreſs and cedar. Theſe being always green, and loaded with very large tops, are much expoſed to the wind and eaſily blown down, the boggy ground affording but a ſlender hold to the roots. Neither beaſt, bird, inſect or reptile, approach the heart of this horrible deſert; perhaps deterred by the everlaſting ſhade, occaſioned by the thick ſhrubs and buſhes, which the ſun can never penetrate, to warm the earth: nor indeed do any birds care to fly over it, any more than they are ſaid to do over the lake Avernus, for fear of the noiſome exhalations that riſe from this vaſt body of filth and naſtineſs. Theſe noxious vapours infect the air round about, giving agues and other diſtempers to the neighboring inhabitants. On the weſtern border of the Diſmal is a pine ſwamp, above a mile in breadth, great part of which is covered with water knee deep; the bottom, however, is firm, and the pines grow very tall, and are not eaſily blown down by the wind. With all theſe diſadvantages, the Diſmal is, in many places, pleaſing to the eye, though diſagreeable to the other ſenſes.

This dreadful ſwamp was judged impaſſable, till the line, dividing Virginia from N. Carolina, was carried through it, in N. lat. 36. 28. in the year 1728, by order of king George II. Although it happened then to be a very dry ſeaſon, the men who were employed in puſhing the line were not altogether free from apprehenſions of being ſtarved; it being 10 whole days before the work was accompliſhed, though they proceeded with all poſſible diligence and reſolution, and beſides had no diſaſter to retard them.

This ſwamp is chiefly owned by two companies. The Virginia company, of which General Waſhington is one, owns 100,000 acres: the North-Carolina company owns 40,000 acres. In the midſt of the ſwamp is a lake, about 7 miles long, called Drummond's pond, whoſe waters diſcharge themſelves to the S. into Paſquotank river, which empties into Albemarle ſound; on the N. into Elizabeth and Nanſemond rivers, which fall into James river. A navigable canal is now digging to connect the navigable waters of the Paſquotank and Elizabeth rivers. The diſtance about 14 miles. This canal will paſs about a mile E. of Drummond's pond, and will receive water from it. The Canal company are incorporated by the concurring laws of Virginia and North-Carolina. This canal, when finiſhed, will open an inland navigation from the head of Cheſapeak bay, including all the rivers in Virginia, to Georgetown in South Carolina; and when the ſhort canal from Elk river to Chriſtiana creek is opened, the communication will extend to Philadelphia and the other ports connected with Delaware river. Such an extenſive inland communication muſt be beneficial in time of peace, and in time of war will be eſſentially ſerviceable.—*ib.*

DITTON (Humphry) an eminent mathematician, was born at Saliſbury, May 29, 1675. Being an only ſon, and his father obſerving in him an extraordinary good capacity, determined to cultivate it with a good education. For this purpoſe he placed him in a reputable private academy, upon quitting of which he, at the deſire of his father, though againſt his own inclination, engaged in the profeſſion of divinity, and began to exerciſe his function at Tunbridge in the county of Kent, where he continued to preach ſome years; during which time he married a lady of that place.

But a weak conſtitution, and the death of his father, induced Mr Ditton to quit that profeſſion. And at the perſuaſion of Dr Harris and Mr Whiſton, both eminent mathematicians, he engaged in the ſtudy of mathematics; a ſcience to which he had always a ſtrong inclination. In the proſecution of this ſcience, he was much encouraged by the ſucceſs and applauſe he received: being greatly eſteemed by the chief profeſſors of it, and particularly by Sir Iſaac Newton, by whoſe intereſt and recommendation he was elected maſter of the new mathematical ſchool in Chriſt's Hoſpital; where he continued till his death, which happened in 1715, in the 40th year of his age, much regretted by the philoſophical world, who expected many uſeful and ingenious diſcoveries from his aſſiduity, learning, and penetrating genius.

Dixon's ‖ Domingo.

machine, that which approaches neareſt to the diving-bell is in a book on fortification by Lorini; who deſcribes a ſquare box bound round with iron, which is furniſhed with windows, and has a ſtool affixed to it for the diver. This ingenious contrivance appears, however, to be older than that Italian; at leaſt he does not pretend to be the inventor of it.

In the year 1617, Francis Keſsler gave a deſcription of his water-armour intended alſo for diving, but which cannot really be uſed for that purpoſe. In the year 1671, Witſen taught, in a better manner than any of his predeceſſors, the conſtruction and uſe of the diving-bell; but he is much miſtaken when he ſays that it was invented at Amſterdam. In 1679 appeared, for the firſt time, Borelli's well known work *de motu animalium*, in which he not only deſcribed the diving-bell, but alſo propoſed another, the impracticability of which was ſhewn by James Bernoulli. When Sturm publiſhed his *Collegium curioſum* in 1678, he propoſed ſome hints for the improvement of this machine, on which remarks were made in the *Journal des ſçavans*. To him ſucceeded Dr Halley, whoſe bell is well known.

DIXON's *Sound*, on the N. W. coaſt of N. America, is the paſſage into the ſound between the main land and Waſhington's or Queen Charlotte's iſlands, from the N. W. This ſeems to be what is called in America *Barrell's Sound*.—*Morse*.

DOBB's *Ferry*, on Hudſon river, is 26 miles above New-York city.—*ib.*

Dobb's *Co.* in Newbern diſtrict, N. Carolina, has been divided into two counties, viz. Glaſgow and Lenoir, ſince the cenſus of 1790, and the name no longer exiſts. It contained 6893 inhabitants, of whom 1915 were ſlaves.—*ib.*

DODECATEMORY, the 12 houſes or parts of the zodiac of the primum mobile. Alſo the 12 ſigns of the zodiac are ſometimes ſo called, becauſe they contain each the 12th part of the zodiac.

DOG-RIBBED *Indians*, inhabit round lake Edlande, in the N. W. part of N. America. They are often at war with the Arathapeſcow Indians Both theſe tribes are among the moſt ſavage of the human race. They trade with the Hudſon bay company's ſettlements. Eolande lake lies N. of the Arathapeſcow ſea, or lake, and near the arctic circle.—*Morse*.

DOME, See Arch in this Supplement.

DOMINGO, or St Domingo. See Hispaniola, both in *Encycl.* and in this Supplement.

Domingo, St, an iſland in the Atlantic ocean, at the entrance of the gulf of Mexico, is one of the four great Antilles, the largeſt of them all, except the iſland of Cuba, and proved the cradle of European power in the new world. Chriſtopher Columbus landed on it the 6th of Dec. 1492. The natives called it *Hayti*, ſignifying high or mountainous land. Charlevoix ſays it was called *Quiſqueya*, that is, great country, or mother of countries. Others ſay it had the name of *Bohio*, which means, a country full of habitations and villages. Columbus called it *Hiſpaniola*, or Little Spain, which name the Spaniards ſtill retain, though St Domingo is the name commonly uſed by other nations; ſo called from *St Domingo*, the capital of the Spaniſh part; which was thus named by Columbus in honor of his father. St Domingo is ſituated between 17. 55. and 20. N. latitude, and between 71. and 77. W. longitude from Paris. It lies 45 leagues E. N. E. of Jamaica, 22 S. E. of Cuba, and 20 N. W. by W. of Porto Rico; and is, not including the ſmall dependent iſlands that ſurround it, 160 leagues long from E. to W. and from 60 to 70 broad from N. to S. When the Spaniards diſcovered the iſland, there were on it at leaſt a million of happy inhabitants, and Bartholomew de las Caſas ſays there were three millions. Such, however, were the cruelties of the Spaniards, and to ſuch an infamous height did they carry their oppreſſion of the poor natives, that they were reduced to 60,000 in the ſhort ſpace of 15 years! It formed five kingdoms, each governed by ſovereigns called caciques. The names of theſe kingdoms were *Maqua*, *Marien*, *Higuay*, *Maguana*, and *Xaraguay*. The Spaniards had poſſeſſion of the whole of the iſland for 120 years. At laſt, about the year 1630, a handful of Engliſh, French, and other Europeans, came and forced them to fight in its defence, and after repeated wars for 50 years, they were forced to divide the iſland with the French. Theſe latter, being the only ſurvivors of the firſt free-booters or buccaniers, or having inſenſibly acquired an aſcendancy among them, had, ſo early as 1640, formed this aſſembly of individuals, born under the domination of almoſt all the powers of Europe, into a French colony, under the direction of the general government, firſt eſtabliſhed at St Chriſtophers, and afterwards at Martinico. The Spaniſh part is by far the moſt extenſive and the moſt fertile; that of the French the beſt cultivated. The whole iſland now belongs to the French republic, the Spaniards having ceded their part of it to that power in the treaty of 1795.

The Spaniards, however ungrateful to the diſcoverer of the new world during his life, would not leave his duſt out of their territories. The remains of Columbus, who died the 20th of May, 1506, were firſt depoſited in Seville, afterwards removed to the cathedral in the city of St Domingo, and laſtly conveyed to the Havannah in a 74 gun ſhip; and on the 19th of January, 1796, all that was mortal of that great man, was committed to the earth the third time, with great parade and ceremony.

The following particulars relating to this famous iſland are founded on the beſt authority, and many circumſtances require a ſeparate view of the two artificial diviſions of the iſland, viz. the French and Spaniſh territories, before they were united under one head. They are both alike in poſſeſſing the various productions common to the W. Indies. The European cattle are ſo multiplied here that they run wild in the woods; few of theſe are in the French part in compariſon with the Spaniſh.

The two great chains of mountains, which extend from E. to W. and their numerous ſpurs, give the iſland an aſpect, at a diſtance, not ſo favourable as it deſerves. They are, however, the cauſe of the fertility of the iſland. They give ſource to innumerable rivers, repel the violence of the winds, vary the temperature of the air, and multiply the reſources of human induſtry. They abound with excellent timber, and mines of iron, lead, copper, ſilver, gold, ſome precious ſtones, and even mercury.—With reſpect to the vegetable claſs in this iſland, it would be difficult, even in a work devoted to the ſubject, to expreſs or paint all

their

Domingo.

The moſt ancient town in this iſland, and in all America, built by Europeans, is St Domingo; of which an account is given below. To theſe particular obſervations, we add the following, of a more general nature: The ſugar and indigo plantations were in the flat, the coffee in the mountainous lands. The plantations were for the moſt part encloſed with live hedges, ſtraight and well dreſſed; the dwelling and manufactory houſes were built and laid out with great neatneſs and taſte; every habitation poſſeſſed a private hoſpital for the accommodation of its ſick negroes, who were parentally dealt with; the roads were excellent; and from the general hoſpitality and cheerfulneſs of its former inhabitants, it was conſidered as one of the moſt enviable ſpots on earth. Such was the French part of St Domingo in 1789; but, alas! it is no more: the deſtructive ravages of an unrelenting inſurrection, of frightful maſſacres and conflagrations, have laid waſte all thoſe beautiful ſettlements, reduced the buildings to aſhes, and laid low in duſt or ſcattered in exile, its wretched inhabitants.

The firſt interference of the National Aſſembly, in the affairs of the colonies, was by a decree of the 8th of March, 1790, which declared, "That all free perſons, who were proprietors and reſidents of two years ſtanding, and who contributed to the exigencies of the ſtate, ſhould exerciſe the rights of voting, which conſtitute the quality of French citizens." This decree, though in fact it gave no new rights to the people of color, was regarded with a jealous eye by the white planters; whoſe pride and reſentment dictated to them to repel the people of color from their aſſemblies. This ſeems to be the true ſource of their calamities; to develope which, and the dreadful conſequences, belong to the profeſſed hiſtorian.—*Morse.*

Domingo, St, the capital of the Spaniſh part of the iſland of St Domingo or Hiſpaniola, is ſituated on the W. bank of the Ozama, a league below the mouth of Iſabella river, in which diſtance it is 24 feet deep, having a bottom of mud or ſoft ſand, and banks 20 feet perpendicular height; but N. of the city this height is reduced to 4 feet. The Ozama is navigable for 9 or 10 leagues, and has ſeveral ſugar manufactories, tile kilns, and proviſion farms on its banks. The road before the mouth of the Ozama is very indifferent, and lies expoſed from W. S. W. to E. It is impoſſible to anchor in it in the time of the ſouth winds; and the north winds drive the veſſels from their moorings out into the ſea, which here runs extremely high. The port of St Domingo is magnificent in every reſpect; a real natural baſon, with a great number of careenings for the veſſels that can get at them. There is a rock at the entrance, which will only admit veſſels drawing 18 or 20 feet water; which it is aſſerted might be removed without great difficulty.

The city of St Domingo was originally founded on the E. ſide of the Ozama, in 1494, by Bartholomew Columbus, who gave it the name of New-Iſabella. Authors aſſert that Chriſtopher Columbus gave it the name of his father, and that the inhabitants of Iſabella on the N. coaſt of the iſland, founded by Chriſtopher Columbus in 1493, removed to New-Iſabella in 1496. In 1502 a hurricane deſtroyed moſt of its buildings, which induced Ovando to remove the inhabitants to the W. ſide of the river. The new city was ſoon built, and that with a grandeur of deſign not unworthy of the firſt metropolis of the New World. The plan of the city is a trapezium of about 540 fathoms on the E. ſide, along the Ozama; near 500 fathoms on the S. bordering on the ſea; and of about 1800 fathoms in circumference. To the W. and to the N. of the city, the land is rough and rocky for about half a league, but after that it becomes good, and the country delightful. Towards the ſea the ſcite of the city lies very high, which forms an inſurmountable dyke againſt the fury of the waves. It is ſurrounded with a rampart 8 feet in diameter, and about 10 feet high. There is a great deal of ordnance at St Domingo, particularly caſt ordnance, but the fortifications are not ſtrong; and the height of the Ileignes commands it entirely; and its crown is not more than 250 fathoms from the ditch. The ſtreets are ſpacious, and ſtraight as a line, which gives it a pleaſing appearance. Ten of theſe ſtreets run from N. to S. and 10 others from E. to W. The greateſt part of the houſes, firſt built, are of a ſort of marble found in the vicinity, and in the ſtyle of the ancient towns of Spain and Italy: thoſe of a more recent conſtruction are of tapia, a ſort of piſe. To erect theſe buildings, a caſe is made of planks, between pillars of maſonry: this caſe is filled by degrees with a reddiſh clay, which is rammed down as it is thrown in, until it forms a ſolid, or ſort of wall, between the pillars. The clay thus preſſed together, acquires an amazing hardneſs, and the walls are ſometimes ſo ſolid and ſtrong, that the pillars of maſonry are uſeleſs. The houſes of St Domingo are tolerably handſome, in a ſimple ſtyle, and nearly uniform. A conſiderable part of theſe, built within theſe 15 years, are of wood, covered with the leves or taches of palm trees. The roofs are generally platformed, being ſhaped ſo as to conduct the rain-water to the ciſterns. The climate of the capital is, happily, very temperate. The nights of thoſe months which anſwer to the winter in Europe, are even found to be cold.

Among a number of public edifices that merit attention, in this declining city, we may reckon the ruins of the houſe that Diego, ſon of Chriſtopher Columbus, had begun, entirely of hewed ſtone. The walls are yet remaining, and ſome of the ſculpture round the windows. The roof and ceilings are fallen in, the lower floor is become a pen for cattle; and a Latin inſcription over the portal, is now hidden by the hut of a herdſman. The cathedral, of the ſame ſort of ſtone as the houſe of Diego Columbus, ſtands on the S. E. Oppoſite its entrance is a fine ſpacious oblong ſquare, at the S. W. end of which is the town houſe. The cathedral is a noble Gothic pile begun in 1512, and finiſhed in 1540, and was conſtructed after the model of a church at Rome. It merits admiration on account of the boldneſs of its vault, which, notwithſtanding the ravages of earthquakes in its neighbourhood, has never, till within theſe 15 or 20 years, had a ſingle flaw. The duſt of Columbus reſted within this pile until the year 1796, when it was removed. Here are 3 convents for men; which have increaſed in importance ſince 1782; 2 nunneries, 3 hoſpitals, a college, and a gaol. The convent of the Cordeliers was built by Ovando in 1503, on a little hill containing a mine of mercury. All the 3 parochial churches of St Domingo, are beautiful, rich in ornaments, in tility of the land, ſays he, is ſuch, that its cultivation cannot fail to promiſe a favourable harveſt. Every where are ſeen an endleſs number of cocoa-nut trees, beautiful banana trees, ranged in lines with the greateſt order, and numerous plantations of potatoes, of which he deſcribes ſome as fifteen feet in length, and of the thickneſs of a man's thigh. He admired the order with which every thing was diſpoſed. No weeds were ſuffered to grow between the plants; and their roads were kept in repair with a diligence deſerving imitation by the moſt civilized nations.

Their government appears from his account to be deſpotic. The ſovereign, who is called the *Tubou*, is held in the higheſt veneration by his ſubjects, whoſe lives and properties are at his diſpoſal. Under him there is an order of nobles called *Equis*, who, though they ſhrink into inſignificance in the preſence of the *Tubou*, have great authority over the people. Theſe people are ſaid by Maurelle to be of great muſcular ſtrength and large ſtature, the ordinary height of the men being ſix feet or ſix feet four inches, while many of them are much taller. It would appear, too, that they delight in gymnaſtic exerciſes; for when the *Tubou*, by whom he had been treated with great hoſpitality, wiſhed to amuſe him and his ſhip's company, he exhibited to them feats of wreſtling and boxing, and that as well by the women as by the men.

Though theſe people put the greateſt confidence in the Spaniards, and frequently ſtaid whole nights on board the frigate, they had yet the common inclination of ſavages to ſteal. "Every time they came on board (ſays our author), clothes, iron-work, whatever fell in their way, they conſidered as lawful prize. They drew out through the port holes, or the windows, whatever was within their reach. They thieved even to the very chain of the rudder. I made my complaints to the king; he gave me permiſſion to kill whomſoever I ſhould detect in the act; and I was aſſured he had himſelf diſcovered and puniſhed with death the authors of the complained of theft. Our vigilance was neceſſarily called into action. We ſurpriſed the iſlanders ſtriving to tear away the new rudder chains; we fired a piſtol at them, one of them fell dead on the occaſion, and this was an awful leſſon for thoſe who were either on board or alongſide of the frigate; they ſaid to themſelves, or to one another *chito* (robber) *fama* (death)."

They make of the bark of trees a kind of cloth not unlike that which has been brought from other iſlands in the South Sea; and our author deſcribes the women as being peculiarly neat both in their dreſs and in their perſons. They had their mantles or looſe garments adjuſted in neat plaits and folds, and becomingly attached by a knot over the left ſhoulder. They wore garlands or wreaths on the head, and chaplets of large glaſs beads round their necks; the hair was pleaſingly diſpoſed in treſſes, and the whole perſon perfumed with an oil of an agreeable odour; above all, the ſkin was ſo exquiſitely clean, that they would not have ſuffered the ſmalleſt particle of duſt to remain upon it a moment.

In this archipelago Don Maurelle found a ſafe harbour, to which he gave the name of El Refugio, and which he places in South Lat. 18°. 36′. and W. Lon. 177°. 47′. 45″. of Greenwich.

DONDON, an interior ſettlement in the French part of the iſland of St Domingo, 3 leagues N. W. of St Raphael in the Spaniſh part, and 13 leagues E. by N. of Les Gonaives.—*Morſe.*

DONEGAL. There are 3 townſhips in Pennſylvania of this name; the one in Lancaſter co. the other in that of Weſtmoreland, and the third in Waſhington co.—*ib.*

DOOBOUNT *Lake*, newly diſcovered, about 60 or 70 miles long, and 20 or 30 broad; lies ſouth-eaſt of the head of Cheſterfield inlet, in New South Wales. —*ib.*

DORCHESTER, a townſhip in Grafton co. New-Hampſhire, incorporated in 1761. In 1790 it contained 175 inhabitants. It lies N. E. of Dartmouth College about 17 miles.—*ib.*

DORCHESTER, an ancient and thriving townſhip in Norfolk co. Maſſachuſetts, ſettled as early as 1630. A number of towns have been taken off from it ſince its firſt ſettlement. It is ſituated 2 miles S. by E. of Boſton, and is now about 6 miles long and 3½ broad. The chief manufactures here are paper, chocolate, ſnuff, leather, and ſhoes of various ſorts. It has a handſome church, 256 houſes, and 1722 inhabitants. The N. E. point of the peninſula, called Dorcheſter neck, approaches within half a mile of Caſtle iſland, and its N. W. point within half a mile of the S. part of Boſton. Forts were erected on the heights in the late war; and this town and its vicinity ſuffered much during the early part of the war.—*ib.*

DORCHESTER, in Cumberland co. New-Jerſey, lies on the E. ſide of Morris river, about 5 miles from its mouth in the bay, and 17 eaſtward of Fairfield.—*ib.*

DORCHESTER *Co.* in Maryland, lies on the E. ſide of Cheſapeak bay; on the S. ſide of Choptank river, which ſeparates it from Talbot co. It has ſeveral iſlands on its coaſt. The chief of theſe, from the mouth of Hudſon river, are, James, Taylor's, Barren, Hooper's, and Goldſborough's, which laſt lies between Hungary river and Fiſhing bay. The length of the county from E. to W. is about 33 miles, and its breadth from N. to S. 27 miles. The number of its inhabitants 15,875, of whom 5337 are ſlaves. The lands in the northern parts are ſomewhat elevated, but in the ſouthern parts low and marſhy, particularly along Fiſhing bay, and up its waters, Tranſquaking, Blackwater, and Fearim creek, and along Hungary river an arm of the Cheſapeak. The produce is chiefly wheat, corn and lumber. Its chief town is Cambridge.—*ib.*

DORCHESTER, a ſmall town of Charleſton diſtrict, South-Carolina, ſeated on the N. E. bank of Aſhley river, 18 miles W. N. W. of Charleſton city.—This place was ſettled and named as early as 1700, by a colony from Dorcheſter and its vicinity in Maſſachuſetts; and a part of its inhabitants, about the year 1750, left it and ſettled Midway, in Georgia.—*ib.*

DORLACH, a townſhip in Otſego co. New-York. By the ſtate cenſus of 1796, 433 of its inhabitants are electors.—*ib.*

DORSET, a townſhip in Bennington co. Vermont, having Rupert W. Mancheſter S. and Danby N.; and contains 958 inhabitants, 27 miles N. by E. of Bennington.—*ib.*

DOUGLASS, a townſhip, the ſouthernmoſt in Worceſter co. Maſſachuſetts, having the ſtate of Rhode-Iſland on the S. and that of Connecticut on the S. W.

and through it paſſes the middle road from Boſton to New-York. It is a very rocky townſhip, and contains 1080 inhabitants. It lies 16 miles S. of Worceſter, and 47 S. W. of Boſton. It was incorporated anno 1746, and received its name in honor of William Douglaſs, M. D. of Boſton, a native of Scotland, and a conſiderable benefactor to the town.—*ib.*

Douglass, a townſhip in Montgomery co. Pennſylvania.—*ib.*

Douglass, a cape on the N. W. coaſt of N. America, which forms the W. ſide of the entrance into Cook's river, oppoſite Point Bede, which forms the E. ſide. It is a very lofty promontory, whoſe elevated ſummit appears above the clouds, forming two exceeding high mountains. Lat. 58. 56. N. long. 206. 10. E.—*ib.*

DOUTY'*s Falls*, in York co. Maine, a place where a poſt office is kept; 7 miles from Berwick, and 8 from Sanford.—*ib.*

DOVER, a townſhip in Norfolk co. Maſſachuſetts, incorporated anno 1650. It contains 485 inhabitants, and lies 15 miles ſouthward of Boſton.—*ib.*

Dover, a conſiderable townſhip in Strafford co. New-Hampſhire, and the ſhire town of the county; ſituated on the ſouthern ſide of Cochecho river, about 4 miles above its junction with Salmon Fall river, which together form the Piſcataqua; 10 miles S. by E. of Rocheſter, 6 from Berwick, in Maine, and 12 N. W. by N. from Portſmouth. The Indians named it Winichahanat and Cochecho; by the firſt ſettlers, it was called Northam. It was incorporated in 1633, and contains 1998 inhabitants. The public buildings are a Congregational church, court-houſe and gaol. At Dover is a high neck of land, between the main branch of Piſcataqua and Back river, about two miles long, and half a mile wide, riſing gently along a fine road and declining on each ſide, like a ſhip's deck. It commands an extenſive and variegated proſpect of the rivers, bays, adjacent ſhores, and diſtant mountains. It has often been admired by travellers as an elegant ſituation for a city, and by military gentlemen for a fortreſs. The firſt ſettlers pitched here, but the trade has long ſince been removed to Cochecho falls; and this beautiful ſpot is almoſt deſerted of inhabitants. N. lat. 43. 11. W. long. 70. 50.—*ib.*

Dover, a townſhip in Monmouth co. New-Jerſey, between Shrewſbury and New-Stafford, and extends from the ſea to the county line. Although a large townſhip, it contains only 910 inhabitants, who live moſtly upon the ſea-ſhore. There is but one church, the property of a generous and benevolent individual; who gives liberty to miniſters of all denominations to preach in it whenever they pleaſe.—*ib.*

Dover, the metropolis of Delaware ſtate, in Kent co. on the S. W. ſide of Jones creek, about 4½ miles N. W. from its mouth, in the Delaware; 12 miles from Duck creek, 48 from Wilmington, and 76 S. S. W. of Philadelphia. It contains about 100 houſes, built principally of brick. There are 4 ſtreets, which interſect each other at right angles, in the centre of the town. The area included within theſe interſections extends into a ſpacious parade; on the E. ſide of which is an elegant ſtate-houſe. The town has a lively appearance, and drives on a conſiderable trade with Philadelphia, chiefly in flour. N. lat. 39. 10. W. long. 75. 34.—*ib.*

Dover, a town in York co. Pennſylvania, on Fox Run, which falls into Conewago creek, near its mouth, in the Suſquehanna. It contains a German Lutheran and Calviniſt church, united; and about 40 houſes.—*ib.*

DOWNE, or *Downs*, a townſhip in Cumberland co. New-Jerſey.—*ib.*

DOWNINGS, a poſt town of Pennſylvania, in Cheſter co. on the E. ſide of Brandywine creek; 33 miles W. by N. of Philadelphia, and near 7 N. W. of Weſtcheſter.—*ib.*

DOYLSTOWN, a village in Bucks co. Pennſylvania, 10 miles S. W. of Howell's ferry, on Delaware river, 15 N. W. of Newton, and 33 W. by N. of Philadelphia.—*ib.*

DRACŒNA Draco (ſee Dracoena, *Encycl.*), is a native of Madeira, though it is there becoming ſcarce. The following account of it is by La Martiniere, naturaliſt in the laſt voyage of diſcovery by La Perouſe. "The idea of the dracœna draco (ſays he) given by the ſhabby ſpecimens cultivated in our hot-houſes, is far inferior to that we entertain of it when we have an opportunity of ſeeing it in its native ſoil. I met with three in particular, of which the trunk was ſix or ſeven feet high, and four and a half or five in diameter. The principal branches, 12 or 15 in number, and as thick as a man's body, ſhoot out a little obliquely, dividing themſelves generally into two, and now and then into three, to the height of 40 or 50 feet including the ſeven feet of the trunk. The leaves are all at the extremity of the branches, where they are placed in alternate order, and form a cluſter. This tree preſents the moſt perfect regularity to the eye, and tempts the ſpectator to think, that the moſt ſkilful gardener makes it the object of his daily care."

DRACUT, a townſhip in the northernmoſt part of Middleſex co. on the northern bank of Merrimack river oppoſite Patucket Falls. It contains 1217 inhabitants, and lies 30 miles N. by W. of Boſton, and 28 S. W. of Exeter, in New-Hampſhire.—*Morse.*

DRAINS. Under this word in the Encyclopædia we publiſhed Mr Bayley of Hope's method of draining land; and by a letter from the author, we have ſince learned, that experience, the beſt guide, has fully proved the uſefulneſs and durability of his *drains*. With a candour, however, worthy of a man who writes not for fame, but for the good of the public, he informs us of a miſtake into which he had led us; and requeſts us to correct it in this Supplement.

"I wiſh (ſays he) that, in the Supplement to the Encyclopædia, due notice may be taken of a very great error into which I was led in my ſcheme of making the *main drains*. I conjectured, that where the bottom of the trench was of a hard or ſolid body, as *clay* or *marl*, it might not be neceſſary to lay it with bricks or ſtones; but in this I was quite wrong. By the runs of water, the alternate changes from wet to dry, and the acceſs of air, theſe hard bottoms have been rendered friable; they have crumbled away, and let in all my drains which were not ſupported by a bottom laid with brick or ſtone." For this information we requeſt the author to accept of our thanks, and we are perſuaded we may add, the thanks of the public.

As the draining of land is a matter of great importance in agriculture, and as the ſubject has been again brought before us, we imagine that our agricultural readers will be glad to find here the ſubſtance of a paper on this ſubject, for which the author received the ſilver medal of the *Society* inſtituted for the encouragement of Arts, Manufactures, and Commerce. That author is Mr John Wedge, of Bickenhill near Coventry, who is not only a great farmer himſelf, but had likewiſe been employed by the Earl of Alesford in the management of ſeveral eſtates. Encouraged by his lordſhip's liberality, Mr Wedge informs the ſociety, that he had been employed for ſome years in draining large portions of land, of which part was in the Earl's occupation, and part in his own, as tenant to his lordſhip. The principles upon which he proceeded, as well as his mode of procedure, he ſtates in the following terms :

In every country there are large portions of land that, in wet ſeaſons, have always what may be called a *dry ſurface*, and other portions of land that have always a *moiſt* or *wet ſurface ;* the former of theſe admitting all the water which falls upon them to ſink freely through their pores to various depths, till falling on clay, or ſome other unctuous earth, whoſe pores will not permit it to paſs through, it is there held up to a height proportioned to the quantity of water which comes upon it, and the facility with which that water is diſcharged. Thus, held up to various heights, it ſerves as a fountain to diſtribute its water (either by veins of ſand, pebbles or rock), according to the formation of the different under ſtrata on the neighbouring lands, and there forms bogs and other varieties of wet ſurface, on a baſis that will be always found to conſiſt of marl, or clay, or ſome mixture thereof. The effect of water thus diſtributed may be divided into two claſſes. The firſt claſs, where the water is thrown out by a body of marl or clay, &c. upon the ſurface of deſcending ground, and in the valley (there held up by clay alſo) forms bogs or ſwamps. The ſecond claſs, where the water is held up by marl or clay, as before, having above that marl or clay a ſtratum of ſand, or pebbles, through which the water paſſes ; and above thoſe ſands or pebbles another ſtratum of marl or clay, through the weakeſt parts of which, the water, by a continual preſſure from its fountain, forces a paſſage upwards ; and thus, through the weakeſt parts of the marl or clay, furniſhes a continual ſupply of water on the ſurface, for the formation or growth of bogs, &c. in proportion as this water is more or leſs abundantly ſupplied by its fountain or head, namely, the higher lands, into which rain-water freely paſſes, as before deſcribed. There are alſo different ſoils under different circumſtances, which may form a third claſs of land for draining ; ſuch as ſtrong deep ſoils, or open light ſoils, having near the ſurface a body of marl or clay. In either of theſe caſes, the water which falls on the ſurface muſt, for reaſons which are ſelf evident, keep ſuch lands, in rainy ſeaſons, conſtantly wet and cold ; and it ſhould be obſerved, that a mixture of all the three before-deſcribed claſſes of wet land ſometimes occur in one field, by ſudden alterations of the under ſtrata, and thereby perplex the operator, by requiring all the different modes of draining in the ſame field.

If it be admitted that bogs are thus formed and fed, their cure may be effected with certainty. The firſt claſs, by cutting through the ſtratum (be it ſand, pebbles, or rock,) that conveys the water to the bog, and carrying off that water by a cloſe drain to ſome proper place, where the level admits of its diſcharge. The ſecond claſs, by ſinking a drain to any convenient depth in the upper clay ; and then digging or boring with a large auger, at a ſmall diſtance on one ſide of this drain, through the remaining part, be it (the upper clay) ever ſo deep, into the under ſtratum of ſand, pebbles, or rock, through which the water paſſes ; which will then ruſh up into the drain ſo made, with a velocity proportioned to the height of the land or fountain whence it is ſupplied. As this drain advances through the land, holes muſt be dug or bored, as before, every ſeven yards, or at ſuch diſtance as the ſtrength of the ſprings may require ; and the whole of the water thus brought up by tapping the ſprings, is carried off by the drain made in the upper clay, which muſt be a cloſe one, to its proper level, and there diſcharged.

By both theſe methods of draining, large tracts of land, under favourable circumſtances, may be cured with one drain. The beſt place for fixing theſe drains is where the ſtratum that conveys the water comes neareſt to the ſurface ; and the beſt method of aſcertaining that, is to bore or dig in different parts through the different under ſtrata.

The third claſs may be eaſily cured by cloſe drains, at ſuch diſtances and depths as will beſt carry off the ſurface-water. It may not be improper to obſerve that where the different ſtrata or meaſures crop out, that is, become gradually more and more ſhallow in ſome certain direction (as is often the caſe, till, one after the other, they all preſent themſelves in ſucceſſion on the ſurface of the earth), draining may often be much more eaſily and better effected by croſſing with the drain the different ſtrata or meaſures where the levels and other circumſtances will admit.

Some of the land drained was part of a common, in the pariſh of Church Bickenhill, in the county of Warwick ; part of it was covered with moſs and ling, had a peaty ſurface about ſix inches deep, and produced little or no graſs : in all wet ſeaſons it was filled quite to the ſurface, and often overflowed, with water. Some of the land was much more unſound, deeper of peat, and covered with moſs, in moſt parts nine inches long ; another part was an abſolute bog in all ſeaſons.

Having dug or bored with a large auger into ſeveral parts of the land, Mr Wedge found peat, gravel, and ſand mixed, and a quick-ſand almoſt uniformly. The quick-ſand in every part, after getting an inch or two into it, ſeemed almoſt as fluid as water. Judging from this, that no materials for a drain could be laid in the quick-ſand, but what it would immediately bury, he dug a trench almoſt to the quick-ſand, leaving gravel, &c. of ſufficient ſtrength to bear up the materials for a hollow drain ; theſe materials were two ſides and a coverer of ſtone, with a peat-turf on the top to keep out the ſoil. At every ſeven yards forward, by the ſide of this drain, he dug a hole in the quick-ſand as deep as it would permit. From theſe holes the water roſe freely into the hollow drain, and was by it diſcharged at a proper level. It may be proper to remark, that the ſtone made uſe for this drain, and all others here mentioned, was a red ſand and rag-ſtone, which eaſily ſplit into proper ſizes for the purpoſe, and is very durable ; it coſt about ſixpence per ton getting, excluſive of carriage. The drain thus formed ran on the whole rather freely, and made the land dry for a few yards on each ſide thereof, but was far from having the effect he improperly expected; for it evidently appears that the drain could only take a very ſmall portion of the water from ſo large a quick-ſand, which it did not penetrate more than two inches; and that it could drain only to its own depth, or at moſt, to that depth in the fountain which ſupplied the quick-ſand. His purpoſe was then defeated; and his motive for mentioning this error cannot, he hopes, be miſtaken.

He now did what he ſays he ought to have done before, that is, examined the different ſtrata to a greater depth, particularly on the bog, and at the upper edges thereof, and found the bog to be what has been deſcribed under the firſt claſs. He therefore determined to attempt the cure in the manner before preſcribed for that claſs, namely, to cut through the whole of the ſtratum (in this inſtance, of quick-ſand), through which he found the water paſs. This he effected as follows: The ſummer being dry, and favourable for the purpoſe, and having previouſly made his main open drain, he began his main cloſe drain the firſt week in June 1791, three feet wide, on the declivity near the edge of the great bog. In the firſt operation he dug through the peat, the hard ſand, and gravel, and one ſpade's graft (about nine inches deep, and ſeven inches wide) into the quick-ſand the whole length of this drain, which was 73 perches, of eight yards to the perch, in length. The drain thus dug ran copiouſly, not leſs than 60 gallons per minute. In this ſtate he left it about nine days: the effect of it was rapid, both above the drain and on the bog below. Upon examination, he now found about three inches on the top of the ſpade's graft, which had been made into the quick-ſand, perfectly dry. He then dug out theſe three inches of dry ſand, to nearly the whole width of the drain, three feet; and at the ſame time dug out, as before, another ſpade's graft from the top of the quick-ſand, as near the middle of the drain as poſſible. This was left to run a few days, as before, and had the ſame effect, namely, three or four inches more of the top of the quick-ſand became dry and hard. The ſame operation was repeated again and again with the ſame effect, till the purpoſe of getting through this quick-ſand was completed, ſo far at leaſt as the level of the main open drain would permit. The ſtream of water continued increaſing during the whole operation; the bog below the drain was quite dry, and the land above perfectly ſo. The drain which was firſt made, and continued running for ſome time during the progreſs of the main cloſe drain, became gradually dry; and has not, ſince that drain was finiſhed, diſcharged one ſingle drop of water. Great care was neceſſary, in making the main cloſe drain, to keep the ſtream of watar in the middle of it, otherwiſe the current would have undermined the ſides, as it ſometimes had done, and cauſed them to fall in. For this reaſon it was neceſſary, when the dry ſand was taken from the top of the quick-ſand, immediately to take out a ſpade's graft from the middle thereof, in order to divert the current from the ſides.

The main cloſe drain thus made was three feet wide at top, about nine feet deep on the average, and, bevelling a little from the top, it was about one foot ten inches wide at the bottom. The ſtone and other materials were put into this drain in the following manner:

Where the drain went through the quick-ſand into the ſtratum of clay below it, as in moſt places it did, the bottom, and in ſome inſtances the ſides, wanted no particular ſecurity (A); but where it did not go quite through the quick-ſand, which the level of his main open drain in ſome places would not admit, the bottom of the drain was covered half an inch thick with ling; then peat-turfs, one foot wide and three or four inches thick, were cut in convenient lengths, and placed on their edges on each ſide of the bottom of the drain, forming two ſides of a trough of peat; then ſide ſtones about eight inches high, and a ſtone coverer, were put in upon the ling between the peat-turfs; a large peat-turf, near two feet wide and four inches thick, was then cut, and firmly placed over the whole; this left in the bottom of the drain an open ſpace, of more than ſix inches ſquare, for the water to paſs. The whole was then completed by filling in the upper part of the drain.

In this way the author drained, for about L. 80, thirty acres of land, which, from being of no value whatever, became worth at leaſt 14 ſhillings per acre of yearly rent. He likewiſe hollow drained nine acres by the method preſcribed for the third claſs of wet land. Theſe drains were made a few yards below that part of each field where the dry and wet land ſeparate, about 22 inches deep, with ſides and a coverer of ſtone, and ling on the top of it, to keep the earth from running in. The length of theſe drains was 880 yards, and the expence of labour and materials three halfpence per yard. The drains, in wet weather, diſcharge a large quantity of water; and will, he has no doubt, anſwer the intended purpoſe. Thus far relates to land in his own occupation.

Nine acres of the land in the earl of Aylesford's occupation was almoſt an entire pulp. This bog was of the ſecond claſs, namely, water paſſing through a quick-ſand, and confined by a ſtratum of clay below, and another ſtratum of clay above it. The water thus confined, being preſſed by its fountain, and forced up thro' the weakeſt parts of the clay, had formed a bog of irregular thickneſs on the ſurface, in ſome places ſix feet deep, in others not more than two. As there is a conſiderable fall in this land from eaſt to weſt, he thought it expedient to put two drains into it; and this appears to him to have been neceſſary, from a conſideration that both theſe drains continue to run in the ſame proportions as when firſt opened. The manner in which theſe drains were executed was, by digging through the different upper ſtrata, and as deep into the clay as the main open drain would admit; then digging or boring through the remaining part of that clay into the quick-ſand, at the diſtance of about ſix yards, in a progreſſive manner.

The water riſing rapidly through theſe holes into the cloſe drains, has effected a complete cure of this land, every part of which will now bear a horſe to gallop upon it. Theſe drains diſcharge 3660 gallons an hour; which

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(A) He will probably find in time that he was under the ſame miſtake with Mr Bayley, and we hope that with Mr Bayley's candour he will acknowledge it.

which is much leſs than they did at firſt, as muſt be the caſe in all bogs. This land will be worth twenty ſhillings per acre. The draining coſt twenty-five pounds; and the length of the under-ground drains is eight hundred and fourteen yards.

Mr Wedge had juſt finiſhed (January 1792) draining another piece of land, about forty-three acres. As this was intended to anſwer two purpoſes, one, to drain the land, the other, to give an additional ſupply of water to a mill-pool, and as a circumſtance aroſe in the execution of the work which frequently happens in draining land, namely, a ſudden alteration in the poſition of the under ſtrata—a deſcription thereof will not, we hope, be thought tedious. This draining was begun at the level of a mill pool, and continued, without any great difficulty, to the diſtance of about thirty-two chains, in the manner before deſcribed as a cure for the ſecond claſs of boggy land; but at or near that place the under ſtrata altered their poſition; the quick-ſand which conveyed the water now became of twice its former thickneſs; and the clay, which had hitherto been above that quick-ſand, for ſome diſtance diſappeared. From the quick-ſand thus becoming ſo much deeper, he could not, with the level of the mill-pool, cut through it; nor indeed, from the wetneſs of the ſeaſon, would ſuch an operation have been proper. He therefore continued a ſhallow drain to ſome diſtance, making ſide-holes into the quick-ſand, which ran freely; but as this could not cure the whole of the bog below, he branched out another drain (which was made by the method deſcribed for curing the ſecond claſs of wet or boggy land), by ſinking a cloſe drain through the upper ſtrata into the upper clay, and then, at a ſmall diſtance on one ſide of this cloſe drain, boring a hole with an auger through the remaining part of that clay into the quick-ſand; and at every eight yards, as this cloſe drain advanced, ſtill boring other holes, in the manner before deſcribed: through many of theſe holes the water ruſhed with great rapidity. The water diſcharged by theſe drains into the mill-pool is 168 gallons per minute, or 3780 hogſheads in a day; which is after the rate of 1,379,700 hogſheads in a year.

About ſix acres of this land were always ſound; about twelve acres on the north ſide were an abſolute pulp, and the remaining twenty-ſix acres very unſound. The whole is now ſound, and will when cultivated be worth ſixteen ſhillings per acre. This land would have been drained at a much leſs expence into the main open drain; but then the water, which was much wanted for the mill, would have been loſt. Theſe cloſe drains are in length 1452 yards, and coſt L. 100, of which about L. 30 ought to be charged to the mill.

Important as this ſubject is, we muſt not enlarge this article, or we ſhould make large extracts from Dr Anderſon's *Practical Treatiſe on Draining Bogs and Swampy Grounds*, lately publiſhed. It is proper, however, to inform the public, that the author puts in his claim for being the firſt diſcoverer of that mode of draining for which Mr Elkington has obtained from parliament a premium of L. 1000; and the reader who ſhall turn to the article DRAINS in the Encyclopædia, will perceive that his claim is well-founded.

DRAKE, a harbour in California, ſo called after the celebrated Sir Francis Drake, who diſcovered and took poſſeſſion of the peninſula of California, for his miſtreſs, Queen Elizabeth. N. lat. 28. 15. W. long. 111. 39.—*Morſe.*

DRAKE, SIR FRANCIS, or *Drake's Bay*, a baſon in the middle of the Virgin iſles, in the Weſt-Indies, 3 or 4 leagues broad, and 6 or 7 long, the fineſt that can be imagined; and in which ſhips may anchor, landlocked, and ſheltered from all winds.—*ib.*

DRESDEN, a townſhip in Lincoln co. diſtrict of Maine, ſituated 9 miles from Wiſcaſſet Point, 15 from Fort Weſton, at Hallowell, and 180 N. by E. of Boſton. Swan Iſland is in this townſhip.—*ib.*

DROMORE, a townſhip in Lancaſter co. Pennſylvania.—*ib.*

DROSSERA ANGLICANA, or the SUNDEW (ſee DROSSERA, *Encycl.*), is a very minute villous plant, uſually growing entangled with moſs on peat bogs; the leaves are curiouſly fringed with numerous ſtrong reddiſh hairs, terminated by ſmall pellucid globules of viſcous liquor, which occaſion, by the reflection of the ſun, that peculiar luſtre from which its name is derived. It is in theſe hairs that the eſſential properties of the plant reſide; for if a ſmall inſect ſhould fix itſelf on one of the leaves, theſe hairs immediately begin to cloſe, one by one, till the inſect is wholly environed by them, and then the leaf in which it is impriſoned gradually bends inwards, ſo as to reach the baſe: in this ſtate the inſect is killed by the operation of the acrimonious juice exuding from the ends of the hairs. Rothius (as quoted by Withering, in his Arrangement of Britiſh Plants,) mentions the effects of this ſingular plant, occaſioned by the irritation of an ant, which he placed on the centre of one of the leaves with a pair of pincers. The ant, in endeavouring to eſcape, was held faſt by the viſcous juice of the ſmaller hairs till the large ones, together with the edges of the leaf, cloſed in and impriſoned it. The ant died in fifteen minutes; but he obſerves, that the effects followed ſooner or later, in different experiments, according to the ſtate of the weather. Dr Withering has publiſhed a ſimilar account of the ſenſitive properties of the Sundew, which was communicated to him by two of his botanical friends, and which he has made very entertaining and intereſting. The ſame thing is confirmed by a writer in the Monthly Magazine for Auguſt 1797; who ſays, that whenever he made experiments on the droſſera with ants and other diminutive inſects, he commonly found them periſh in a ſhorter time than fifteen minutes. His experiments were made on the droſſera rotundifolia. Rothius, however, obſerves, that the longifolia produces the ſame effects, but with greater rapidity. In concluding his account, Dr Withering ſuggeſts this enquiry: "Whether this deſtruction of inſects be not neceſſary to the welfare of the plant?" And it is ſurely worth ſome botaniſt's while to take ſome pains to anſwer the queſtion.

DRUGS (ſee *Encycl.*) are ſo commonly counterfeited, or at leaſt adulterated, that in London, the royal college of phyſicians, it is well known, has long ago appointed a court of examiners to inveſtigate the goodneſs of drugs and medicines in the different chemiſts and apothecaries ſhops. The counterfeit, however, is made up with ſuch dexterity, that not only the merchant and drug-broker, but even the man of ſkill is ſometimes deceived: and indeed nothing can detect this impoſition but a practical knowledge of chemiſtry. We therefore recommend it to every father of a family

12 miles W. of Portſmouth. It was incorporated in 1633, and contains 1247 inhabitants. It was formerly a part of Dover, which adjoins it on the N. and was called Oyſter river. On the top of a hill in this town is a rock, computed to weigh 60 or 70 tons, ſo exactly poiſed on another rock as to be eaſily moved by one's finger. Its ſituation appears to be natural. —*ib.*

DURHAM, a townſhip in New-Haven co. Connecticut, ſettled from Guildford in 1698, and incorporated in 1708. It is about 22 miles S. W. of Hartford and 18 miles N. E. of New-Haven. It was called *Chagingchague* by the Indians; which name a ſmall river that chiefly riſes here, ſtill bears.—*ib.*

DURHAM, a townſhip in Bucks co. Pennſylvania. —*ib.*

DUTCHESS *Co.* in New-York, is on the E. ſide of Hudſon river. It has the ſtate of Connecticut on the E. Weſt-Cheſter on the S. and Columbia co. on the N. It is about 48 miles long and 23 broad, and contains 15 townſhips, of which Poughkeepſie and Fiſh-Kill are the chief. It contains 45,266 inhabitants; of theſe 6013 are qualified to be electors, and 1856 are ſlaves. Dutcheſs co. ſends 7 repreſentatives to the aſſembly of the ſtate. In the year 1792, a remarkable cavern was diſcovered in this county, at a place called by the Indians Sepaſcot, at Rhynbeck. A lad, by chance, paſſing near its entrance, which lies between two huge rocks, on the declivity of a ſteep hill, on prying into the gloomy receſs, ſaw the top of a ladder, by which he deſcended about 10 feet, and found himſelf in a ſubterraneous apartment, more capacious than he choſe to inveſtigate. He found, however, that it had been the abode of perſons, who probably during the war, had taken ſhelter here, as bits of cloth and pieces of leather were ſcattered about its floor. It ſince appears to be divided by a narrow paſſage into two apartments; the firſt being about 17 feet in length, and ſo low that a child of eight years old could but juſt walk upright in it; the breadth is about 8 or 10 feet. The ſecond between 12 and 14 feet in length, but much higher and broader than the firſt. Like many other caverns in the United States, it poſſeſſes a petrifying quality; and the water, which is conſtantly percolating through the roofs of its apartments, has formed a variety of tranſparent and beautiful ſtalactites. They have the appearance of icicles, and may be broken off by the hand, if not more than two inches in circumference.

But what is moſt to be admired is the ſkeleton of a large ſnake, turned into ſolid ſtone by the petrifying quality of the water before-metioned. It was with ſome difficulty torn up with an axe from the rock it lay upon, and is now in poſſeſſion of the gentleman who explored the cavern. A want of free air was experienced in the inmoſt receſſes of the cavern, by a difficult reſpiration, though the candles burnt very clear. The air was alſo very warm.—*ib.*

DUTCHMAN's *Point*, a point of land on the Vermont ſide of lake Champlain, about 16 miles S. of the Canada line. The Britiſh held a ſtockaded hut here, garriſoned by ſix ſoldiers, ſince the peace of 1783. It has ſince been delivered up to the United States. —*ib.*

DUXBOROUGH, a maritime townſhip in Plymouth co. Maſſachuſetts, incorporated in 1637. 20 veſſels, the greater part from 60 to 90 tons, are owned here. It is a healthy town, and contains 1460 inhabitants; not a greater number than it contained 50 years ago. It lies S. by E. of Plymouth, 3 miles acroſs Plymouth bay by water, and 8 round by land, and 38 S. E. by S. of Boſton. Within the harbour are Clarke's iſland conſiſting of about 100 acres of excellent land, and Sauquiſh iſland which was formerly joined to the Gurnet, by a narrow piece of land; but the water has inſulated it. The Gurnet is an eminence at the ſouthern extremity of the beach, on which is a light-houſe built by the ſtate. The Indian name of the town was Mattakeeſet, or Namakeeſet. It was ſettled by capt. Standiſh and his aſſociates. The captain came to Plymouth with the firſt ſettlers in 1620.—*ib.*

DUXBURY, a townſhip in Hillſborough co. New-Hampſhire, incorporated in 1763; firſt called Dantzick, joined with Sutton in the enumeration of 1775. It has only 169 inhabitants.—*ib.*

DUXBURY, a townſhip in Chittenden co. Vermont, about 20 miles S. E. of Burlington, and contains 39 inhabitants.—*ib.*

DWARFING OF VEGETABLES, an art invented by the Chineſe, to which the attention of Sir George Staunton was attracted on the following occaſion:

When the embaſſy was at Chuſan (See CHUSAN in this Supplement) the gentlemen who went on ſhore were introduced to the governor in his hall of audience, where on ſeveral tables were placed, in frames filled with earth, dwarf pines, oaks, and orange trees, bearing fruit. None of them exceeded in height two feet. Some of thoſe dwarfs bore all the marks of decay from age: and upon the ſurface of the ſoil were interſperſed ſmall heaps of ſtones, which, in proportion to the adjoining dwarfs might be termed rocks. Theſe were honey-combed and moſs-grown, as if untouched for ages, which ſerved to maintain the illuſion, and to give an antique appearance to the whole. This kind of ſtunted vegetation ſeemed to be much reliſhed by the curious in China, and ſpecimens of it were to be found in every conſiderable dwelling. To produce them formed part of the gardener's ſkill, and was an art invented in that country. Beſide the mere merit of overcoming a difficulty, it had that of introducing vegetables into common apartments, from which their natural ſize muſt otherwiſe have excluded them.

The general method of obtaining vegetable dwarfs is ſaid to be the following: A quantity of clay or mould is applied to the upper part of the trunk of a tree, from which a dwarf is intended to be taken, and cloſe to its diviſion into branches. The mold is to be confined to the ſpot by coarſe hempen or cotton cloth, and to be carefully kept moiſt by water. In conſequence of this application, continued ſometimes above a twelvemonth, ſmall tender fibres ſhoot down like roots from the wood into the mould. The part of the trunk emitting thoſe new fibres, together with the branch riſing immediately above it, is then to be carefully ſeparated from the reſt of the tree, and planted in new earth, in which the fibres become new roots, while the former branch is now the ſtem of the vegetable thus tranſformed in ſome meaſure. This operation does not deſtroy or alter the productive faculty which thoſe parts enjoyed before their ſeparation from their parent root. That which, while a branch of the original tree bore flowers and fruit, continues to produce the ſame, though no longer ſupported upon any ſtock. The terminal buds of ſuch branches of trees as are meant to become dwarfs are torn off; which circumſtance prevents the further elongation of thoſe branches, and forces other buds and branchlets from the ſides. Theſe branchlets are bent by wires to whatever form the operator wiſhes: and when the appearance of age and decay is meant to be given to a dwarf tree, it is repeatedly ſmeared with treacle or molaſſes, which attracts multitudes of ants, who, in purſuit of thoſe ſweet juices, attack the bark, and, by a gradual corroſion of it, produce the deſired effect. Theſe different proceſſes are ſometimes attempted to be kept ſecret by the gardeners, and they vary deſignedly in the mode of carrying them on; but the principle on which they are founded is ſufficiently apparent from what is related here, and the contrivance argues ingenuity and perſeverance, rather than the practice does true taſte, which conſiſts in aſſiſting nature in its moſt favourite works—not in counteracting its operations or diſtorting its productions.

DYEING is an art, into which, ſince the article in the Encyclopædia was publiſhed, improvements have been introduced of ſuch importance, that it would be unpardonable not to notice them in this Supplement. We accordingly agreed for a new article with a teacher of chemiſtry, ſtrongly recommended to us as a man who had long directed his attention to that ſubject; and he ſolemnly engaged to have the article ready for the preſs before the 1ſt of November 1798. It is now the 20th of February 1799; and after amuſing us from week to week, and from day to day, till our patience is quite exhauſted, he finds himſelf unable (for we will not attribute his conduct to a worſe motive) to fulfil his engagement. In this ſtate of things what are we to do? The ſubject muſt not be relinquiſhed, and our numerous preſſes can no longer ſtand unemployed. It is fortunate that, by following the arrangement of Chaptal, ſo well known for the clearneſs of his method, we have yet an opportunity of treating of dyeing under the article *Animal and Vegetable* SUBSTANCES referred to from CHEMISTRY. Such of our readers as are acquainted with the buſineſs of the preſs will deem this ſhort narrative a ſufficient apology for our conduct; and even thoſe of them who are in a great meaſure ſtrangers to that buſineſs, will not think us, circumſtanced as we are, deſerving of much cenſure for delaying a ſubject, which we pledge ourſelves not to omit under the article to which we have referred.

DYNAMICS.

1
Definition.

THIS name marks that department of phyſico-mathematical ſcience which contains the abſtract doctrine of MOVING FORCES; that is, whatever neceſſarily reſults from the relations of our ideas of motion, and of the immediate cauſes of its production and changes.

2
Object of
dynamics is
hange of
hat condi-
ion of a
hing
which we
call its *mo-*
ion.

All *changes* of motion are conſidered by us as the indications, the characteriſtics, and the meaſures of changing cauſes. This is a phyſical law of human thought, and therefore a principle to which we may refer, and from which we muſt derive all our knowledge of thoſe cauſes. When we appeal to our own thoughts or feelings, we do not find in ourſelves any diſpoſition to refer mere exiſtence to any cauſe, although the beginning of exiſtence certainly produces this reference in an inſtant. Had we always obſerved the univerſe in motion, it does not appear that we ſhould have aſcribed it to a cauſe, till the obſervation of relative reſt, or ſomething leading to it, had enabled us to ſeparate, by abſtraction, the notion of matter from that of motion. We might then perceive, that reſt is not incompatible with matter; and we might even obſerve, by means of relative motions, that abſolute reſt might be produced by the concourſe of equal and oppoſite motions. But all this requires reflection and reaſoning; whereas we are now ſpeaking of the firſt ſuggeſtions of our minds.

3 We cannot have any notion of motion *in abſtracto*, without conſidering it as a ſtate or condition of exiſtence, which would remain if not changed by ſome cauſe. It is from changes alone, therefore, that we infer any agency in nature; and it is in theſe that we are to find all that we know of their cauſes.

4
Mechanical relation, what.

When we look around us, we cannot but obſerve, that the motions of bodies have, in moſt caſes, if not always, ſome relation to the ſituation, the diſtance, and the diſcriminating qualities of other bodies. The motions of the moon have a palpable relation to the earth; the motions of the tides have as evident a relation to the moon; the motions of a piece of iron have a palpable dependence on a magnet. The vicinity of the one ſeems to be the occaſion at leaſt of the motions of the other. The cauſes of theſe motions have an evident connection with or dependence on the other body. We are even diſpoſed to imagine that they are inherent in that body, and that it poſſeſſes certain qualities which are the cauſes of thoſe modifications of motion in other bodies. Theſe ſerve to diſtinguiſh ſome bodies from others, and may therefore be called PROPERTIES; and, ſince the condition of other bodies ſo evidently depends on them, theſe properties expreſs very intereſting relations of bodies, and are chiefly attended to in the enumeration of the circumſtances which aſcertain what we call the *nature* of any thing. We do not mean to ſay, that theſe inferences are always juſt; nay, we know that many of them are ill-founded: but they are real, and they ſerve abundantly for informing us what we may expect from any propoſed ſituation of things. It is enough for us to know that when a piece of iron is ſo and ſo ſituated in relation to a magnet, it will move in a certain manner.

This mutual relation of bodies is differently conſidered, according to the intereſt that we chance to take in the phenomenon. The cauſe of the approach of the iron to a magnet is generally aſcribed to the magnet, which is ſaid to attract the iron, becauſe we commonly employ the magnet in order that theſe motions may take place. The ſimilar approach of a ſtone to the earth is aſcribed to the ſtone, and we ſay that it tends to the earth. In all probability, the procedure of nature is the ſame in both; for they are obſerved, in every inſtance, to be mutual between the related bodies. As iron approaches a magnet, ſo the magnet approaches the iron. The ſame thing is obſerved in the motions of electrified bodies; alſo in the caſe of the ſtone and the earth. Therefore the cauſe of the motions may be conceived as inherent in either, or in both.

Force and *Action* are figurative terms when uſed in mechaniſm;

The qualities thus inherent in bodies, conſtituting their mechanical relations, have been called the MECHANICAL AFFECTIONS OF MATTER. But they are more commonly named POWERS or FORCES; and the event which indicates their preſence, is conſidered as the effect and mark of their agency. The magnet is ſaid to ACT on the iron, the earth is ſaid to ACT on the ſtone; and the iron and the ſtone are ſaid to ACT on the magnet and on the earth.

All this is figurative or metaphorical language. All languages have begun with ſocial union, and have improved along with it. The firſt collections of words expreſſed the moſt familiar and the moſt intereſting notions. In the proceſs of ſocial improvement the number of words did not increaſe in the ſame proportion with the notions that became intereſting and familiar in their turn: for it often happened that relations of certain ideas ſo much reſembled the relations of certain other ideas, that the word expreſſing one of them ſerved very well for expreſſing the other; becauſe the diſſimilar circumſtances of the two caſes prevented all chance of miſtake. Thus we are ſaid to *ſurmount* a difficulty, without attaching to the word the notion of *getting over* a ſteep hill. Languages are thus filled with figurative expreſſions.

5
But the analogy is not in the force, but in the effect.

POWER, FORCE, and ACTION, are words which muſt have appeared in the language of the moſt ſimple people; becauſe the notions of perſonal ability, ſtrength, and exertion, are at once the moſt familiar and the moſt intereſting that can have a place in the human mind. Theſe terms, when uſed in their pure primitive ſenſe, expreſs the notions of the power, force and action of a ſentient, active, being. Such a being only is an agent. The exertion of his power or force is (excluſively) action: But the relation of cauſe and effect ſo much reſembles in its reſults the relation between this force and the work performed, that the ſame term may be very intelligibly employed for both. Perhaps the only caſe of pure unfigurative action is that of the mind on the body. But as this is always with the deſign of producing ſome change on external bodies, we think only of them; the inſtrument or tool is overlooked, and we ſay that we act on the external body. Our *real* action therefore is but the firſt movement in a long train of ſucceſſive events, and is but the remote cauſe of the intereſting event. The reſemblance to ſuch actions is very ſtrong indeed in many caſes of mechanical phenomena. A man throws a ball by the motion of his arm. A ſpring impels a ball in the ſame manner by unbending. Theſe two events reſemble each other in every circumſtance but the action of the mind on the corporeal organ—the reſt of it is a train of pure mechaniſm. In general, becauſe the ultimate reſults of the mutual influence of bodies on each other greatly reſemble the ultimate reſults of our actions on bodies, we have not invented appropriated terms, but have contented ourſelves with thoſe already employed for expreſſing our own actions, the exertions of our own powers or forces. The relation of phyſical cauſe and effect is expreſſed metaphorically in the words which belong properly to the relation of agent and action. This has been attended by the uſual conſequences of poverty of language, namely, ambiguity, and ſometimes miſtake, both in our reflections, (which are generally carried on by mental diſcourſe), our reaſonings, and our concluſions. It is neceſſary to be on our guard againſt ſuch miſtakes; for they frequently amount to the confounding of things totally different. Many philoſophers of great reputation, on no better foundation than this metaphorical language, have confounded the relations of activity and of cauſation, and even denied that there is any difference; and they have affirmed, that there is the ſame invariable relation between the determinations of the will and the inducements that prompt them, as there is between any phyſical power and its effect. Others have maintained, that the firſt mover in the mechanical operations, and indeed through the whole train of any complicated event, is a percipient and intending principle in the ſame manner as in our actions. According to theſe philoſophers, a particle of gravitating matter perceives its relation to every other particle in the univerſe, and determines its own motion according to fixed laws, in exact conformity to its ſituation. But the language, and even the actions of all men ſhew, that they have a notion of the relation of an agent to the action, eaſily diſtinguiſhable (becauſe all diſtinguiſh it) from the relation between the phyſical cauſe and its effect. The proofs of this fact have been adduced in other parts of the Encyclopædia, as, for example, in the article PHILOSOPHY, n° 42. and in this Supplement in the article ACTION.

Theſe remarks are not made in this place for any philological purpoſe, ſuch as the mere improvement of language, but becauſe this metaphorical language has affected the doctrines of mechanical philoſophy, and has produced a diſpute about ſome of its firſt principles; and becauſe we find, that the only way to decide this diſpute is to avoid, moſt ſcrupulouſly, all metaphorical language, though at the expence of much circumlocution.

6
Directions for the ſafe employment of this analogy.

When we ſpeak of powers or forces as reſiding in a body, and the effect as produced by their exertion, the body, conſidered as poſſeſſing the power, is ſaid to ACT on the other. A magnet is ſaid to act on a piece of iron; a billiard ball in motion is ſaid to act on one that is hit by it: but if we attempt to fix our attention on this action, as diſtinct both from the agent and the thing acted on, we find no object of contemplation.—The exertion or procedure of nature in producing the effect does not come under our view. When we *ſpeak* of the action as diſtinct from the agent, we find that it is not the action, properly ſpeaking, but the act that we ſpeak of. In like manner, the action of a mechanical power can be conceived only in the effect produced.

7
Action implies change; and mere motion is not action.

A man is not ſaid to act unleſs he produces ſome effect. Thought is the act of the thinking principle; motion of the limb is the act of the mind on it. In mechanics, alſo, there is action only in ſo far as there is mechanical effect produced. I muſt act violently in order to begin motion on a ſlide: I muſt exert force, and this force exerted produces motion. I conceive the production of motion, in all caſes, as the exertion of force; but it requires no exertion to continue the motion along the ſlide; I am conſcious of none, therefore I ought to infer that no force is neceſſary for the continuation of any motion. The continuation of motion is not the production of any new effect, but the permanency of an effect already produced. We indeed conſider motion as the effect of an action; but there would be no effect if the body were not moving. Motion is not the action, but the effect of the action.

8
Preſſion, impulſion.

Mechanical actions have been uſually claſſed under two heads: they are either PRESSURES or IMPULSIONS. They are generally conſidered as of different kinds; the exertions of different powers. PRESSURE is ſuppoſed to differ eſſentially from IMPULSE.

Inſtead of attempting to define, or deſcribe, theſe two kinds of forces and actions, we ſhall juſt mention ſome inſtances. This will give us all the knowledge of their diſtinctions that we can acquire.

Examples of preſſion.

When a ball lies on a table, and I preſs it gently on one ſide, it moves toward the other ſide of the table. If I follow it with my finger, continuing my preſſure, it accelerates continually in its motion. In like manner, when I preſs on the handle of a common kitchen jack, the fly *begins* to move. If I continue to urge or preſs round the handle, the fly accelerates continually, and may be brought into a ſtate of very rapid motion. Theſe motions are the effects of genuine preſſure. The ball would be urged along the table in the ſame manner, and with a motion continually accelerated, by the unbending of a ſpring. Alſo, a ſpring coiled up round the axis of the handle of the jack would, by uncoiling itſelf, urge round the fly with a motion accelerating in the ſame way. The more I reflect on the preſſure of my finger on the ball, and compare it with the effect of the ſpring on it, the more clearly do I ſee the perfect ſimilarity; and I call theſe influences, exertions, or actions, by one name, PRESSURE, taken from the moſt familiar inſtance of them.

Again, the very ſame motion may be produced in the ball or fly, by pulling the ball or the machine by means of a thread, to which a weight is ſuſpended. As both are motions accelerated in the ſame manner, I call the influence or action of the thread on the ball or machine by the ſame name PRESSURE, and WEIGHT is conſidered as a preſſing power. Indeed I feel the ſame compreſſion from the real preſſure of a man on my ſhoulders that I would feel from a load laid on them. But the weight in our example is acting by the intervention of the thread. By its preſſure it is pulling at that part of the thread to which it is faſtened; this part is pulling at the next by means of the force of coheſion; and this pulls at a third, and ſo on, till the moſt remote pulls at the ball or the machine. Thus may elaſticity, weight, coheſion, and other forces, perform the office of a genuine power; and ſince their reſult is always a motion beginning from nothing, and accelerating by perceptible degrees to any velocity, this reſemblance makes us call them by one familiar name.

But farther, I ſee that if the thread be cut, the weight will fall with an accelerated motion, which will increaſe to any degree if the fall be great enough. I aſcribe this alſo to a preſſing power acting on the weight. Nay, after a very little refinement, I conſider this power as the cauſe of the body's weight; which word is but a diſtinguiſhing name for this particular inſtance of preſſing power. Gravitation is therefore added to the liſt of preſſures; and for ſimilar reaſons, the attractions and repulſions of magnets or electric bodies may be added to the liſt. For they produce actual compreſſions of bodies placed between them, and they produce motions gradually accelerated, preciſely as gravitation does. Therefore all theſe powers may be diſtinguiſhed by this deſcriptive name *preſſures*, which, in ſtrict language, belongs to one of them only.

Gravity, attractions, and repulſions, are conſidered as preſſions.

Several writers, however, ſubdivide this great claſs into preſſions and ſolicitations. Gravity is a ſolicitation *ab extra*, by which a body is urged downward. In like manner, the forces of magnetiſm and electricity, and a vaſt variety of other attractions and repulſions, are called *ſolicitations*. We ſee little uſe for this diſtinction, and the term is too like an affection of mind.

9
Examples of impulſion.

IMPULSION is exhibited when a ball in motion puts another ball into motion by hitting, or (to ſpeak metaphorically) by ſtriking it. The appearances here are very different. The body that is ſtruck acquires, in the inſtant of impulſe a ſenſible quantity of motion, and ſometimes a very rapid motion. This motion is neither accelerated nor retarded after the ſtroke, unleſs it be affected by ſome other force. It is alſo remarked, that the rapidity of the motion depends, *inter alia* on the previous velocity of the ſtriking body; for inſtance, if a clay ball, moving with any velocity, ſtrike another equal ball which is at reſt, the ſtruck ball moves with half the velocity of the other. And it is farther remarkable, that the ſtriking body always loſes as much motion as the ſtruck body gains. This univerſal and remarkable fact ſeems to have given riſe to a confuſed or indiſtinct notion of a ſort of transference of motion from one body to another. The phraſeology in general uſe on this ſubject expreſſes this in the moſt preciſe terms. The one ball is not ſaid to cauſe or produce motion in the other, but to *communicate* motion to it; and the whole phenomenon is called the *communication of motion*. We call this an *indiſtinct* notion; for ſurely no one will ſay that he has any clear conception of it. We can form the moſt diſtinct notion of the communication of heat, or of the cauſe of heat; of the communication of ſaltneſs, ſweetneſs, and a thouſand other *things;* but we cannot conceive how part of that identical motion which was formerly in A, is now infuſed into B, being given up by A. It is in our attempt to form this notion that we find that motion is not a *thing*, not a ſubſtance which can exiſt independently, and is ſuſceptible of actual transference. It appears in this caſe to be a ſtate, or condition, or mode of exiſtence, of which bodies are ſuſceptible, which is producible, or (to ſpeak without metaphor) cauſable in bodies, and which is the effect and *characteriſtic* of *certain* natural qualities, properties or powers. We are anxious to have our readers impreſſed with clear and preciſe notions on this ſubject, being confident that ſuch, and only ſuch, will carry them through ſome intricate paths of mechanical and philoſophical reſearch.

Communication of motion, not a good expreſſion.

10
Inherent force is the diſtinctive character of the impulſion,

The remarkable circumſtance in this phenomenon is, that a rapid motion, which requires for the effecting it to preſſure, may be produced by motion. Thus, two balls connected by a thread, may be ſo ſtruck that they ſhall move forward, and at the ſame time wheel round. In this caſe the connecting thread will be ſtretched between them. Now, ſay the philoſophers, ſince we ſee motion, and ſee that preſſure may be produced by motion, it is prepoſterous to imagine that it is any thing elſe than a reſult of certain motions; and it is the buſineſs of a philoſopher to inquire and diſcover what motions produce the preſſures that we obſerve.

They then proceed to account for thoſe preſſing powers, or ſolicitations to motion, which we obſerve in the acceleration of falling bodies, the attractions of magnetiſm and electricity, and many other phenomena of this kind, where bodies are put in motion by the vicinity of other bodies, or (in the popular language) by the action of other bodies at a diſtance. To ſay that a magnet can act on a piece of remote iron, is to ſay that it can act *where* it is not; which is as abſurd as to ſay, that it can act *when* it is not. *Nihil movetur,* ſays Euler, *niſi a contiguo et moto.*

ow does produce eſſure?

The bulk of theſe philoſophers are not very anxious about the way in which theſe motions are produced, nor do they fall upon ſuch ingenious methods of producing preſſure as the one already mentioned, which was adduced by Euler. The piece of iron, ſay they, is put in motion when brought into the neighbourhood of a magnet, becauſe there is a ſtream of fluid iſſuing from one pole of the magnet, which circles round the magnet, and enters at the other pole: This ſtream impels the iron, and arranges it in certain determined poſitions, juſt as a ſtream of water would arrange the flote graſs. In the ſame manner, there is a ſtream of fluid continually moving towards the centre of the earth, which impels all bodies in lines perpendicular to the ſurface; and ſo on with regard to other like phenomena. Theſe motions are thus reduced to very ſimple caſes by impulſion.

compa- ble with e rules of ilosophi- ng.

It is unneceſſary to refute this doctrine at preſent; it is enough that it is contrary to all the dictates of common ſenſe. To *ſuppoſe* an agent that we do not ſee, and for whoſe exiſtence we have not the ſmalleſt argument; with equal propriety we might ſuppoſe miniſtering ſpirits, or any thing that we pleaſe.

13 thers aintain at preſ- re is the le moving rce.

Other philoſophers are ſo diſſatisfied with this notion of the production of preſſure, that they, on the other hand, affirm that preſſure is the only moving force in nature; not according to the popular notion of preſſure, by the mutual contact of ſolid bodies, but that kind of preſſure which has been called *ſolicitation;* ſuch as the power of gravity. They affirm, that there is no ſuch thing as contact on inſtantaneous communication of motion by real colliſion. They ſay (and they prove it by very convincing facts (ſee OPTICS, n° 63—68. *Encycl.*), that the particles of ſolid bodies exert very ſtrong repulſions to a ſmall diſtance; and therefore, when they are brought by motion ſufficiently near to another body, they repel it, and are equally repelled by it. Thus is motion produced in the other body, and their own motion is diminiſhed. And they then ſhew, by a ſcrupulous conſideration of the ſtate of the bodies while the one is advancing and the other retiring, in what manner the two bodies attain a common velocity, ſo that the quantity of motion before colliſion remains unchanged, the one body gaining as much as the other loſes. They alſo ſhew caſes of ſuch mutual action between bodies, where it is evident that they have never come into contact; and yet the reſult has been preciſely ſimilar to thoſe caſes where the motion appeared to be changed in an inſtant. Therefore they conclude, that there is no ſuch thing as inſtantaneous *communication,* or transfuſion of motion, by contact in colliſion or impulſe. The reaſon why previous motion of the impelling body is neceſſary, is not that it may have a *vis inſita corpori moto,* a force inherent in it *by its being in motion,* but that it may continue to follow the impelled and retiring body, and exert on it a force inherent in itſelf, whether in motion or at reſt.—According to theſe philoſophers, therefore, all moving forces are of that kind which has been named *ſolicitation;* ſuch as gravity. We ſhall know it afterwards by the more familiar and deſcriptive name of ACCELERATING or RETARDING force.

14 *Action, Reſiſtance, Reaction.*

The exertions of mechanical forces are differently termed, according to the reference that we make to the reſult. If, in boxing or wreſtling, I ſtrike, or endeavour to throw my antagoniſt. I am ſaid to ACT; but if I only parry his blows, or prevent him from throwing me, I am ſaid to RESIST. This diſtinction is applied to the exertions of mechanical powers. When one body A changes the motion of another B, we may conſider the change in the motion of B either as the indication and meaſure of A's power of producing motion, or as the indication and meaſure of A's reſiſtance to the being brought to reſt, or having its motion any how changed. The diſtinction is not in the thing itſelf, but only in the reference that we are diſpoſed, by other conſiderations, to make of its effect. They may be diſtinguiſhed in the following manner: If a change of motion follow when one of the powers ceaſes to be exerted, that power is conceived as having reſiſted. The whole language on this ſubject is metaphorical. Reſiſtance, effort, endeavour, &c. are words which cannot be employed in mechanical diſcuſſions without figure, becauſe they all expreſs notions which relate to ſentient beings; and the unguarded indulgence of this figurative language has ſo much affected the imagination of philoſophers, that many have almoſt animated all matter. Perhaps the word REACTION, introduced (we think) by Newton, is the beſt term for expreſſing that mutual force which is perceived in all the operations of nature that we have inveſtigated with ſucceſs. As the magnet attracts iron, and in ſo doing is ſaid to *act* on it; ſo the iron attracts the magnet, and may be ſaid to *react* on it.

15 We need not ſuppoſe action at a diſtance. *Tendency.*

With reſpect to the difficulty that has been objected to the opinion of thoſe who maintain that all the mechanical phenomena are produced by the agency of attracting or repelling forces; namely, that this ſuppoſes the bodies to act on each other at a diſtance, however ſmall thoſe diſtances may be, which is thought to be abſurd, we may obſerve, that we may aſcribe the mutual approaches or receſſes to tendencies to or from each other. What we call *the attraction of the magnet* may be conſidered as a tendency of the iron to the magnet, ſomewhat ſimilar to the gravitation of a ſtone toward the earth. We ſurely (at leaſt the unlearned) can and do conceive the iron to be affected by the magnet, *without thinking* of any intermedium. The thing is not therefore inconceivable; which is all that we know about abſurdity: and we do not know any thing about the nature or eſſence of matter which renders this tendency to the magnet impoſſible. That we do not ſee intuitively any reaſon why the iron ſhould approach the magnet, muſt be granted; but this is not enough to intitle us to ſay, that ſuch a thing is impoſſible or inconſiſtent with the nature of matter. It appears, therefore, to be very haſty and unwarrantable, to ſuppoſe the impulſe of an inviſible fluid, of which we know nothing, and of the exiſtence of which we have no proof. Nay, if it be true that bodies do not come into contact, even when one ball hits another, and drives it before it, this inviſible fluid will not ſolve the difficulty; becauſe the ſame difficulty occurs in the action of any particle of the fluid on the body. We are obliged to ſay, that the production of motion without any *obſerved* contact, is a much more familiar phenomenon than the production of motion by impulſion. More motion has been produced in this way by the gravitation of a ſmall ſtream of water, running ever ſince the creation, than by all the impulſes in the world twice told. We do not mean by this to ſay, that the giving to this obſerved mutual relation between iron and a loadſtone the name tendency makes it leſs abſurd, than when we ſay that the loadſtone attracts the iron; it only makes it more conceivable: It ſuggeſts a very familiar analogy; but both are equally figurative expreſſions; at leaſt as the word tendency is uſed at preſent. In the language of ancient Rome, there was no metaphor when Virgil's hero ſaid, *Tendimus in Latium. Tendere verſus ſolem* means, in plain Latin to *approach the ſun*. The ſafe way of conceiving the whole is to ſay, that the condition of the iron depends on the vicinity of the magnet.

16 *Attraction, Repulſion,* are figurative terms.

When the exertions of a mechanical power are obſerved to be always directed toward a body, that body is ſaid to attract. But when the other body always moves off from it, it is ſaid to repel. Theſe alſo are metaphorical expreſſions. I attract a boat when I pull it toward me by a rope; this is purely ATTRACTION: and it is pure, unfigurative REPULSION, when I puſh any body from me. The ſame words are applied to the mechanical phenomena, merely becauſe they reſemble the reſults of real attraction or repulſion. We muſt be much on our guard to avoid metaphor in our conceptions, and never allow thoſe words to ſuggeſt to our mind any opinion about the *manner* in which the mechanical forces produce their effects. It is plain, that if the opinion of thoſe who maintain the exiſtence and action of the above-mentioned inviſible fluid be juſt, there is nothing like attraction or repulſion in the univerſe. We muſt always recur to the ſimple phenomenon, the motion to or from the attracting or repelling body; for this is all we ſee, and generally all that we know.

17 Forces are conceived as meaſurable quantities.

We conceive one man to have twice the ſtrength of another man, when we ſee that he can withſtand the united effort of two others. Thus animal force is conceived as a quantity, made up of, and meaſured by, its own parts. But we doubt exceedingly, whether this be an accurate conception. We have not a diſtinct notion of one ſtrain added to another; though we have of their being joined or combined. We want words to expreſs the difference of theſe two notions in our own minds; but we imagine that others perceive the ſame difference. We conceive clearly the addition of two lines or of two minutes; we can conceive them apart, and perceive their boundaries common to both, where one ends and the other begins. We cannot conceive thus of two forces combined; yet we cannot ſay, that two equal forces are *not* double of one of them. We meaſure them by the effects which they are known to produce. Yet there are not wanting many caſes where the action of two men, equally ſtrong, does not produce a double motion.

How m ſured.

In like manner, we conceive all mechanical forces as meaſurable by their effects; and thus they are made the ſubjects of mathematical diſcuſſion. We talk of the proportions of gravity, magnetiſm, electricity, &c.; nay, we talk of the proportion of gravity to magnetiſm: Yet theſe conſidered in themſelves, are diſparate, and do not admit of any proportion; but they produce effects, ſome of which are meaſurable, and whoſe aſſumed meaſures are ſuſceptible of compariſon, being quantities of the ſame kind. Thus, one of the effects of gravity is the acceleration of motion in a falling body: magnetiſm will alſo accelerate the motion of a piece of iron; theſe two accelerations are comparable. But we cannot compare magnetiſm with heat; becauſe we do not know any meaſurable effects of magnetiſm that are of the ſame kind with any effects of heat.

By their effects.

When we ſay, that the gravitation of the moon is the 3600th part of the gravitation at the ſea ſhore, we mean that the fall of a ſtone in a ſecond is 3600 times greater than the fall of the moon in the ſame time. But we alſo mean (and this expreſſes the proportion of the *tendency* of gravitation more purely), that if a ſtone, when hung on a ſpring ſteelyard, draw out the rod of the ſteelyard to the mark 3600, the ſame ſtone, taken up to the diſtance of the moon, will draw it out no further than the mark 1. We alſo mean, that if the ſtone at the ſea ſhore draw out the rod to any mark, it will require 3600 ſuch ſtones to draw it out to that mark, when the trial is made at the diſtance of the moon. It is not, therefore, in conſequence of any immediate perception of the proportion of the gravitation at the moon to that at the ſurface of the earth that we make ſuch an aſſertion; but theſe motions, which we conſider as its effects in theſe ſituations being magnitudes of the ſame kind, are ſuſceptible of compariſon, and have a proportion which can be aſcertained by obſervation. It is theſe proportions that we contemplate; although we ſpeak of the proportions of the unſeen cauſes, the forces or endeavours to deſcend. It will be of material ſervice to the reader to peruſe the judicious and acute diſſertation on *quantity* in the 45th volume of the Philoſophical Tranſactions; or he may ſtudy the article QUANTITY in the *Encyclopædia*, where, we truſt, he will ſee clearly how force, velocity, denſity, and many other magnitudes of very frequent occurrence in mechanical philoſophy, may be made the ſubjects of mathematical diſcuſſion, by means of ſome of thoſe proper quantities, meaſurable by their own parts, which are to be aſſumed as their meaſures. Preſſures are meaſurable only by preſſures. When we conſider them as moving powers, we ſhould be able to meaſure them by *any* moving powers, otherwiſe we cannot compare them; therefore it is not as preſſures that we then meaſure them. This obſervation is momentous.

One circumſtance muſt be carefully attended to.

continuing to exiſt. But it is far otherwiſe, ſay they, with reſpect to matter in motion. Here the body is continually changing its relations to other things; therefore the continual agency of a changing cauſe is neceſſary (by the fundamental principle of all philoſophical diſcuſſion), for there is here the continual production of an effect. They ſay that this metaphyſical argument receives complete confirmation (if confirmation of an intuitive truth be neceſſary) from the moſt familiar obſervation. We ſee that all motions, however violent, terminte in reſt, and that the continual exertion of ſome force is neceſſary for their continuance.

23 Whimſical notion of elemental minds.

Theſe philoſophers therefore aſſert, that the continual action of the moving cauſe is *eſſentially* neceſſary for the continuance of the motion: but they differ among themſelves in their notions and opinions about this cauſe. Some maintain, that all the motions in the univerſe are produced and continued by the immediate agency of Deity; others affirm, that in every particle of matter there is inherent a ſort of mind, the φυσις and ὁσπερψυχη of Ariſtotle, which they call an Elemental Mind, which is the cauſe of *all* its motions and changes. An overweaning reverence for Greek learning has had a great influence in reviving this doctrine of Ariſtotle. The Greek and Roman languages are affirmed to be more accurate expreſſions of human thought than the modern languages are. In thoſe ancient languages, the verbs which expreſs motion are employed both in the active and paſſive voice; whereas we have only the active verb *to move*, for expreſſing both the ſtate of motion and the act of putting in motion. "The ſtone *moves* down the ſlope, and *moves* all the pebbles which lie in its way;" but in the ancient languages, the mere ſtate of motion is always expreſſed by the paſſive or middle voice. The accurate conception of the ſpeakers is therefore extolled. The ſtate of motion is expreſſed as it ought to be, as the reſult of a continual action." κινειται, *movetur*, is equivalent to "it is moved." According to theſe philoſophers, every thing which *moves* is mind, and every thing that *is moved* is body.

The argument is futile, and it is falſe; for the modern languages are, in general, equally accurate in this inſtance: "*ſe mouvoir*," in French; "*ſich bewegen*," in German; "*dvigatſu*," in Slavonic; are all paſſive or reflected. And the ancients ſaid, that "rain falls, water runs, ſmoke riſes," juſt as we do. The ingenious author of *Ancient Metaphyſics* has taken much pains to give us, at length, the procedures of thoſe elementary minds in producing the oſtenſible phenomena of local motion; but it ſeems to be merely an abuſe of language, and a very frivolous abuſe. This elemental mind is known and characteriſed only by the effect which we aſcribe to its action; that is, by the motions or changes of motions. Uniform and unexcepted experience ſhews us that theſe are regulated by laws as preciſe as thoſe of mathematical truth. We conſider nothing as more fixed and determined than the common laws of mechaniſm. There is nothing here that indicates any thing like ſpontaneity, intention, purpoſe; none of thoſe marks by which mind was firſt brought into view; but they are very like the effects which we produce by the exertions of our corporeal forces, and we have accordingly given the name of *force* to the cauſes of motion. It is ſurely much more appoſite than the name mind, and conveys with much more readineſs and perſpicuity the very notions that we wiſh to convey.

24 Action neceſſar for the continu-ance of motion.

We now wiſh to know what reaſon we have to think that the continual action of ſome cauſe is neceſſary for continuing matter in motion, or for thinking that reſt is its natural ſtate; if we pretend to draw any argument from the nature of matter, that matter muſt be known, as far as is neceſſary, for being the foundation of argument. Its very exiſtence is known only from obſervation; all our knowledge of it muſt therefore be derived from the ſame ſource.

If we take this way to come at the origin of this opinion, we ſhall find that experience gives us no authority for ſaying that reſt is the natural condition of matter. We cannot ſay that we have ever ſeen a body at reſt; this is evident to every perſon who allows the validity of the Newtonian philoſophy, and the truth of the Copernican ſyſtem of the ſun and planets; all the parts of this ſyſtem are in motion. Nay, it appears from many obſervations, that the ſun, with his attending planets, is carried in a certain direction, with a velocity which is very great. We have no unqueſtionable authority for ſaying that any one of the ſtars is abſolutely fixed. But we are *certain* that many of them are in motion. Reſt is therefore ſo rare a condition of body, that we cannot ſay, from any experience, that it is its natural ſtate.

25

It is eaſy, however, to ſee, that it is from obſervation that this opinion has been derived; but the obſervation has been limited and careleſs. Our experiments in this ſublunary world do indeed always require continued action of ſome moving force to continue the motion; and if this be not employed, we ſee the motions ſlacken every minute, and terminate in reſt after no long period. Our firſt notions of ſublunary bodies are indicated by their operation in caſes where we have ſome intereſt. Perpetually ſeeing our own exertions neceſſary, we are led to conſider matter as ſomething not only naturally quieſcent and inert, but ſluggiſh, averſe from motion, and prone to reſt (we muſt be pardoned this metaphorical language, becauſe we can find no other term). What is expreſſed by it, on this occaſion, is preciſely one of the erroneous or inadequate conceptions that are ſuggeſted to our thoughts by reaſon of the poverty of language. We animate matter in order to give it motion, and then we endow it with a ſort of moral character in order to explain the appearance of thoſe motions.

26

But more extended obſervation has made men gradually deſert their firſt opinions, and at laſt allow that matter has no peculiar aptitude to reſt. All the retardations that we *obſerve* have been diſcovered, one after another, to have a diſtinct reference to ſome external circumſtances. The diminution of motion is always obſerved to be accompanied by the removal of obſtacles, as when a ball moves through ſand, or water, or air; or it is owing to oppoſite motions which are deſtroyed; or it is owing to roughneſs of the path, or to friction, &c. We find that the more we can keep thoſe things out of the way, the leſs are the motions diminiſhed. A pendulum will vibrate but a ſhort while in water; much longer in air; and in the exhauſted receiver it will vibrate a whole day. We know that we cannot remove *all* obſtacles; but we are led by ſuch obſervations to conclude that, if they *could be completely removed*, our motions would continue forever. And this concluſion is almoſt demonſtrated by the motions of the heavenly bodies, to which we know of no obſtacles, and which we really obſerve to retain their motions for many thouſand years without the ſmalleſt ſenſible diminution.

27
Inactivity of matter denied by Leibnitz.

Another ſet of philoſophers maintain an opinion directly oppoſite to that of the inactivity of matter, and aſſert, that it is eſſentially active, and continually changing its ſtate. Faint traces of this are to be found in the writings of Plato, Ariſtotle, and their commentators. Mr Leibnitz is the perſon who has treated this queſtion moſt ſyſtematically and fully. He ſuppoſes every particle of matter to have a principle of individuality, which he therefore calls a MONAD. This monad has a ſort of *perception* of its ſituation in the univerſe, and of its relation to every other part of this univerſe. Laſtly, he ſays that the monad acts on the material particle, much in the ſame way that the ſoul of man acts on his body. It modifies the motion of the material atom (in conformity, however, to unalterable laws), producing all thoſe modifications of motion that we obſerve. Matter, therefore, or, at leaſt, particles of matter, are continually active, and continually changing their ſituation.

Monads, what.

This opinion ill-founded.

It is quite unneceſſary to enter on a formal confutation of Mr Leibnitz's ſyſtem of monads, which differs very little from the ſyſtem of elemental minds, and is equally whimſical and frivolous; becauſe it only makes the unlearned reader ſtare, without giving him any information. Should it even be granted, it would not, any more than the action of animals, invalidate the general propoſition which we are endeavouring to eſtabliſh as the fundamental law of motion. Thoſe powers of the monads or of the elemental minds, are the cauſes of all the changes of motion; but the mere material particle is ſubject to the law, and requires the exertion of the monad in order to exhibit a change of motion.

28
Some philoſophers deduce this law of motion from the want of a *determining* cauſe.

A third ſect of philoſophers, at the head of which we may place Sir Iſaac Newton, maintain the doctrine enounced in the propoſition. But they differ much in reſpect of the foundation on which it is built.

Some aſſert that its truth flows from the nature of the thing. If a body be at reſt, and you aſſert that it will not remain at reſt, it muſt move in ſome one direction. If it be in motion in any direction, and with any velocity, and do not continue its equable rectilineal, motion, it muſt either be accelerated or retarded; it muſt turn either to one ſide or to ſome other ſide. The event, whatever it be, is individual and determinate; but no cauſe which can determine it is ſuppoſed: therefore the determination cannot take place, and no change will happen in the condition of the body with reſpect to motion. It will continue at reſt, or perſevere in its rectilineal and equable motion.

But conſiderable objections may be made to this argument of *ſufficient reaſon*, as it is called. In the immenſity and perfect uniformity of ſpace and time, there is no determining cauſe why the viſible univerſe ſhould exiſt in the place in which we ſee it rather than in another, or at this time rather than at another. Nay, the argument ſeems to beg the queſtion. A cauſe of determination is required as eſſentially neceſſary—a determination may be without a cauſe, as well as a motion without a cauſe.

Other philoſophers, who maintain this doctrine, conſider it merely as an experimental truth; and proofs of its univerſality are innumerable.

29
Others deduce it from experience.

When a ſtone is thrown from the hand, we preſs it forward while in the hand, and let it go when the hand has acquired the greateſt rapidity of motion that we can give it. The ſtone continues in that ſtate of motion which it acquired gradually along with the hand. We can throw a ſtone much farther by means of a ſling; becauſe, by a very moderate motion of the hand, we can whirl the ſtone round till it acquire a very great velocity, and then we let go one of the ſtrings, and the ſtone eſcapes, *by continuing* its rapid motion. We ſee it ſtill more diſtinctly in ſhooting an arrow from a bow. The ſtring preſſes hard on the notch of the arrow, and it yields to this preſſure and goes forward. The ſtring alone would go faſter forward. It therefore *continues* to preſs the arrow forward, and accelerates its motion. This goes on till the bow is as much unbent as the ſtring will allow. But the ſtring is now a ſtraight line. It came into this poſition with an accelerated motion, and it therefore goes a little beyond this poſition, but with a retarded motion, being checked by the bow. But there is nothing to check the arrow; therefore the arrow quits the ſtring, and flies away.

Theſe are ſimple caſes of perſeverance in a ſtate of motion, where the procedure of nature is ſo eaſily traced that we perceive it almoſt intuitively. It is no leſs clear in other phenomena which are more complicated; but it requires a little reflection to trace the proceſs. We have often ſeen an equeſtrian ſhowman ride a horſe at a gallop, ſtanding on the ſaddle, and ſtepping from it to the back of another horſe that gallops alongſide at the ſame rate; and he does this ſeemingly with as much eaſe as if the horſes were ſtanding ſtill. The man has the ſame velocity with the horſe that gallops under him, and keeps this velocity while he ſteps to the back of the other. If that other were ſtanding ſtill, the man would fly over his head. And if a man ſhould ſtep from the back of a horſe that is ſtanding ſtill to the back of another that gallops paſt him, he would be left behind. In the ſame manner, a ſlack wire dancer toſſes oranges from hand to hand while the wire is in full ſwing. The orange, ſwinging along with the hand, retains the velocity; and when in the air follows the hand, and falls into it when it is in the oppoſite extremity of its ſwing. A ball, dropped from the maſt-head of a ſhip that is ſailing briſkly forward, falls at the foot of the maſt. It retains the motion which it had while in the hand of the perſon who dropped it, and follows the maſt during the whole of its fall.

We alſo have familiar inſtances of the perſeverance of a body in a ſtate of reſt. When a veſſel filled with water is drawn ſuddenly along the floor, the water daſhes over the poſterior ſide of the veſſel. It is left behind. In the ſame manner, when a coach or boat is dragged forward, the perſons in it find themſelves ſtrike againſt the hinder part of the carriage or boat. Properly ſpeaking, it is the carriage that ſtrikes on them. In like manner, if we lay a card on the tip of the finger, and a piece of money on the card, we may nick away the card by hitting it neatly on its edge; but the piece of money will be left behind, lying on the tip of the finger. A ball will go through a wall and fly onward; but the wall is left behind. Buildings are thrown down by earthquakes; ſometimes by being toſſed from their foundations, but more generally by the ground on which they ſtand being haſtily drawn ſidewiſe from under them, &c.

30
Common experience inſufficient.

But common experience ſeems inſufficient for eſtabliſhing this fundamental propoſition of mechanical philoſophy. We muſt, on the faith of the Copernican ſyſtem, grant that we never ſaw a body at reſt, or in uniform rectilineal motion; yet this ſeems abſolutely neceſſary before we can ſay that we have eſtabliſhed this propoſition experimentally.

What we imagine, in our experiments, to be putting a body, formerly at reſt, into motion, is, in fact, only changing a moſt rapid motion, not leſs, and probably much greater, than 90,000 feet per ſecond. Suppoſe a cannon pointed eaſt, and the bullet diſcharged at noon day with 60 times greater velocity than we have ever been able to give it. It would appear to ſet out with this unmeaſurable velocity to the eaſtward; to be gradually retarded by the reſiſtance of the air, and at laſt brought to reſt by hitting the ground. But, by reaſon of the earth's motion round the ſun, the fact is quite the reverſe. Immediately before the diſcharge, the ball was moving to the weſtward with the velocity of 90,000 feet per ſecond nearly. By the exploſion of the powder, and its preſſure on the ball, ſome of this motion is deſtroyed, and at the muzzle of the gun, the ball is moving ſlower, and the cannon is hurried away from it to the weſtward. The air, which is alſo moving to the weſtward 90,000 feet in a ſecond, gradually communicates motion to the ball, in the ſame manner as a hurricane would do. At laſt (the ball dropping all the while) ſome part of the ground hits the ball, and carries it along with it.

Other obſervations muſt therefore be reſorted to, in order to obtain an experimental proof of this propoſition. And ſuch are to be found. Although we cannot meaſure the abſolute motions of bodies, we can obſerve and meaſure accurately their relative motions, which are the differences of their abſolute motions. Now, if we can ſhew experimentally, that bodies ſhew equal tendencies to reſiſt the augmentation and the diminution of their relative motions, they, *ipſo facto*, ſhew equal tendencies to reſiſt the augmentation or diminution of their abſolute motions. Therefore let two bodies, A and B, be put into ſuch a ſituation, that they cannot (by reaſon of their impenetrability, or the actions of their mutual powers) perſevere in their relative motions. The change produced on A is the effect and the meaſure of B's tendency to perſevere in its former ſtate; and therefore the proportion of theſe changes will ſhew the proportion of their tendencies to maintain their former ſtates. Therefore let the following experiment be made at noon.

Experiments proper for the purpoſe.

Let A, apparently moving weſtward three feet per ſecond, hit the equal body B apparently at reſt. Suppoſe, 1*ſt*, That A impels B forward, without any diminution of its own velocity. This reſult would ſhew that B manifeſts no tendency to maintain its motion unchanged, but that A retains its motion undiminiſhed.

2*dly*, Suppoſe that A ſtops, and that B remains at reſt. This would ſhew that A does not reſiſt a diminution of motion, but that B retains its motion unaugmented.

3*dly*, Suppoſe that both move weſtward with the velocity of one foot per ſecond. The change on A is a diminution of velocity, amounting to two feet per ſecond. This is the effect and the meaſure of B's tendency to maintain its velocity unaugmented. The change on B is an augmentation of one foot per ſecond made on its velocity; and this is the meaſure of A's tendency to maintain its velocity undiminiſhed. This tendency is but half of the former; and this reſult would ſhew, that the reſiſtance to a diminution of velocity is but half of the reſiſtance to augmentation. It is perhaps but one quarter; for the change on B has produced a double change on A.

4*thly*, Suppoſe that both move weſtward at the rate of 1½ feet per ſecond. It is evident that their tendencies to maintain their ſtates unchanged are now equal.

5*thly*, Suppoſe A = 2 B, and that both move, after the colliſion, two feet per ſecond, B has received an addition of two feet per ſecond to its former velocity. This is the effect and the meaſure of A's whole tendency to retain its motion undiminiſhed. Half of this change on B meaſures the perſevering tendency of the half of A; but A, which formerly moved with the apparent or relative velocity three, now moves (by the ſuppoſition) with the velocity two, having loſt a velocity of one foot per ſecond. Each half of A therefore has loſt this velocity, and the whole loſs of motion is two. Now this is the meaſure of B's tendency to maintain its former ſtate unaugmented; and this is the ſame with the meaſure of A's tendency to maintain its own former ſtate undiminiſhed. The concluſion from ſuch a reſult would therefore be, that bodies have equal tendencies to maintain their former ſtates of motion without augmentation and without diminution.

What is ſuppoſed in the 4*th* and 5*th* caſes is really the reſult of all the experiments which have been tried; and this law regulates all the changes of motion which are produced by the mutual actions of bodies in impulſions. This aſſertion is true without exception or qualification. Therefore it appears that bodies have no preferable tendency to reſt, and that no fact can be adduced which ſhould make us ſuppoſe that a motion once begun ſhould ſuffer any diminution without the action of a changing cauſe.

But experience is not the proper foundation of an axiom.

But we muſt now obſerve, that this way of eſtabliſhing the firſt law of motion is very imperfect, and altogether unfit for rendering it the fundamental principle of a whole and extenſive ſcience. It is ſubject to all the inaccuracy that is to be found in our beſt experiments; and it cannat be applied to caſes where ſcrupulous accuracy is wanted, and where no experiment can be made.

Let us therefore examine the propoſition by means of the general principles adopted in the article PHILOSOPHY, *Encycl.* which contain the foundation of all our knowledge of active nature. Theſe principles will, we imagine, give a deciſion of this queſtion that is ſpeedy and accurate; ſhewing the propoſition to be an axiom or intuitive conſequence of the relations of thoſe ideas which we have of motion, and of the cauſes of its production and changes.

31
Logical proof,

It has been fully demonſtrated that the powers or forces, of which we ſpeak ſo much, are never the immediate objects of our perception. Their very exiſtence, their kind, and their degree, are inſtinctive inferences from the motions which we obſerve and claſs. It evidently follows from this experimental and univerſal truth, *1ſt*, That where no change of motion is obſerved, no ſuch inference is made; that is, no power is *ſuppoſed* to act. But whenever any change of motion is obſerved, the inference is made; that is, a power or force is ſuppoſed to have acted.

In the ſame form of logical concluſion, we muſt ſay that, *2dly*, When no change of motion is *ſuppoſed* or thought of, no force is *ſuppoſed;* and that whenever we *ſuppoſe* a change of motion, we, in fact, though not in terms, ſuppoſe a changing force. And, on the other hand, whenever we ſuppoſe the action of a changing force, we ſuppoſe the change of motion; for the action of this force, and the change of motion, is one and the ſame thing. We cannot think of the action without thinking of the indication of that action; that is, the change of motion.—In the ſame manner, when we do not think of a changing force, or ſuppoſe that there is no action of a changing force, we, in fact, though not in terms, ſuppoſe that there is no indication of this changing force; that is, that there is no change.

It is a law of human thought,

Whenever, therefore, we ſuppoſe that no mechanical force is acting on a body, we, in fact, ſuppoſe that the body continues in its former condition with reſpect to motion. If we ſuppoſe that nothing accelerates, or retards, or deflects the motion, we ſuppoſe that it is not accelerated, nor retarded, nor deflected. Hence follows the propoſition in expreſs terms—*We ſuppoſe that the body continues in its former ſtate of reſt or motion, unleſs we ſuppoſe that it is changed by ſome mechanical force.*

Thus it appears, that this propoſition is not a matter of experience or contingency, depending on the properties which it has pleaſed the Author of Nature to beſtow on body: it is, to us, a neceſſary truth. The propoſition does not ſo much expreſs any thing with regard to body, as it does the operations of our mind when contemplating body. It may perhaps be eſſential to body to move in ſome particular direction. It may be eſſential to body to ſtop as ſoon as the moving cauſe has ceaſed to act; or it may be eſſential to body to diminiſh its motion gradually, and finally come to reſt. But this will not invalidate the truth of this propoſition. Theſe circumſtances in the nature of body, which render thoſe modifications of motion eſſentially neceſſary, are the cauſes of thoſe modifications; and, in our ſtudy of nature, they will be conſidered by us as changing forces, and will be known and called by that name. And if we ſhould ever ſee a particle of matter in ſuch a ſituation that it is affected by thoſe eſſential properties alone, we ſhall, from obſervation of its motion, diſcover what thoſe eſſential properties are.

And almoſt an identical propoſition.

This law turns out at laſt to be little more than a tautological propoſition: But mechanical philoſophy, as we have defined it, requires no other ſenſe of it; for, even if we ſhould ſuppoſe that body, of its own nature, is capable of changing its ſtate, this change muſt be performed according to ſome law which characteriſes the nature of body; and the knowledge of the law can be had in no other way than by obſerving the deviations from uniform rectilineal motion. It is therefore indifferent whether thoſe changes are derived from the nature of the thing, or from external cauſes: for in order to conſider the various motions of bodies, we muſt firſt conſider this nature of matter as a mechanical affection of matter, operating in every inſtance; and thus we are brought back to the law enounced in this propoſition. This becomes more certain when we reflect that the external cauſes (ſuch as gravity or magnetiſm,) which are acknowledged to operate changes of motion, are equally unknown to us with this eſſential original property of matter, and are, like it, nothing but inferences from the phenomena.

The above very diffuſe diſcuſſions may appear ſuperfluous to many readers, and even cumberſome; but we truſt that the philoſophical reader will excuſe our anxiety on this head, when he reflects on the complicated, indiſtinct, and inaccurate notions commonly had of the ſubject; and more eſpecially when he obſerves, that of thoſe who maintain the truth of this fundamental propoſition, as we have enounced it, many (and they too of the firſt eminence), reject it in fact, by combining it with other opinions which are inconſiſtent with it, nay, which contradict it in expreſs terms. We may even include Sir Iſaac Newton in the number of thoſe who have at leaſt introduced modes of expreſſion which miſlead the minds of incautious perſons, and ſuggeſt inadequate notions, incompatible with the pure doctrine of the propoſition. Although, in words, they diſclaim the doctrine that reſt is the natural ſtate of body, and that force is neceſſary for the continuation of its motion, yet in words they (and moſt of them in thought) likewiſe abet that doctrine: for they ſay, that there reſides in a moving body a *power* or *force*, by which it perſeveres in its motion. They call it the VIS INSITA, the INHERENT FORCE OF A MOVING BODY. This is ſurely giving up the queſtion: for if the motion is ſuppoſed to be continued in conſequence of a force, that force is *ſuppoſed* to be exerted; and it is ſuppoſed, that if it were not exerted, the motion would ceaſe; and therefore the propoſition muſt be falſe. Indeed it is ſometimes expreſſed ſo as ſeemingly to ward off this objection. It is ſaid, that the body continues in uniform rectilineal motion, unleſs affected by ſome *external cauſe*. But this way of ſpeaking obliges us, at firſt ſetting out in natural philoſophy, to aſſert that gravity, magnetiſm, electricity, and a thouſand other mechanical powers, are external to the matter which they put in motion. This is quite improper: It is the buſineſs of philoſophy to diſcover whether they be external or not; and if we aſſert that they are, we have no principles of argumentation with thoſe who deny it. It is this one thing that has filled the ſtudy of nature with all the jargon of æthers and other inviſible intangible fluids, which has diſgraced philoſophy, and greatly retarded its progreſs.

32
Vis inſita, inherent force, are improper terms in their uſual acceptation.

We muſt obſerve, that the terms *vis inſita*, inherent *force*, are very improper. There is no diſpute among philoſophers in calling every thing a force that produces a change of motion, and in inferring the action of ſuch a force whenever we obſerve a change of motion. It is ſurely incongruous to give the ſame name to what has not this quality of producing a change, or to infer (or rather to ſuppoſe) the energy of a force when no change of motion is obſerved. This is one among many inſtances of the danger of miſtake when we indulge in analogical diſcuſſions. All our language, at leaſt, on this ſubject is analogous. I feel, that in order to oppoſe animal force, I muſt exert force. But I muſt exert force in order to oppoſe a body in motion: Therefore I imagine that the moving body poſſeſſes force. A bent ſpring will drive a body forward by unbending: Therefore I ſay that the ſpring exerts force. A moving body impels the body which it hits: Therefore I ſay, that the impelling body poſſeſſes and exerts force. I imagine farther, that it poſſeſſes force only by being in motion, or becauſe it is in motion; becauſe I do not find that a quieſcent body will put another into motion by touching it. But we ſhall ſoon find this to be falſe in many, if not in all caſes, and that the communication of motion depends on the mere vicinity, and not on the motion, of the impelling body; yet we aſcribe the exertion of the *vis inſita* to the circumſtance of the continued motion. We therefore conceive the force as ariſing from, or as conſiſting in, the impelling body's being in motion; and, with a very obſcure and indiſtinct conception of the whole matter, we call it *the force by which the body preſerves itſelf in motion.* Thus, taking it for granted that a force reſides in the body, and being obliged to give it ſome office, this is the only one that we can think of.

But philoſophers imagine that they perceive the neceſſity of the exertion of a force in order to the continuation of a motion. Motion (ſay they) is a continued action; the body is every inſtant in a new ſituation; there is the continual production of an effect, therefore the continual action of a cauſe.

33
Motion is not the continual production of an effect.

But this is a very inaccurate way of thinking. We have a diſtinct conception of motion; and we conceive that there is ſuch a thing as a moving cauſe, which we diſtinguiſh from all other cauſes by the name *force.* It produces motion. If it does this, it produces the character of motion, which is a continual change of place. Motion is not action, but the effect of an action; and this action is as complete in the inſtant immediately ſucceeding the beginning of the motion as it is a minute after. The ſubſequent change of place is the continuation of an effect already produced. The *immediate* effect of the moving force is a DETERMINATION, by which, if not hindered, the body would go on forever from place to place. It is in this determination only that the ſtate or condition of the body can differ from a ſtate of reſt; for in any inſtant, the body does not deſcribe any ſpace, but has a determination, by which it will deſcribe a certain ſpace uniformly in a certain time. Motion is a condition, a ſtate, or mode, of exiſtence, and no more requires the continued agency of the moving cauſe than yellowneſs or roundneſs does. It requires ſome chemical agency to change the yellowneſs to greenneſs; and it requires a mechanical cauſe or a force to change this motion into reſt. When we ſee a moving body ſtop ſhort in an inſtant, or be gradually, but quickly, brought to reſt, we never fail to ſpeculate about a cauſe of this ceſſation or retardation. The caſe is no way different in itſelf although the retardation ſhould be extremely ſlow. We ſhould always attribute it to a cauſe. It requires a cauſe to put a body out of motion as much as to put it into motion. This cauſe, if not external, muſt be found in the body itſelf; and it muſt have a ſelf-determining power, and may as well be able to put itſelf into motion as out of it.

If this reaſoning be not admitted, we do not ſee how any effect can be produced by any cauſe. Every effect ſuppoſes ſomething *done*; and any thing done implies that the thing done may remain till it be *undone* by ſome other cauſe. Without this, it would have no exiſtence. If a moving cauſe did not produce continued motion by its inſtantaneous action, it could not produce it by any continuance of that action; becauſe in no inſtant of that action does it produce continued motion.

We muſt therefore give up the opinion, that there reſides in a moving body a force by *which it is kept in motion*; and we muſt find ſome other way of explaining that remarkable difference between a moving body and a body at reſt, by which the firſt cauſes other bodies to move by hitting them, while the other does not do this by merely touching them. We ſhall ſee, with the cleareſt evidence, that motion is neceſſary in the impelling body, in order that it may permit the forces inherent in one or both bodies to continue this preſſure long enough for producing a ſenſible or conſiderable motion. But theſe moving forces are inherent in bodies, whether they are in motion or at reſt.

34
Communication of motion is an improper phraſe.

The foregoing obſervations ſhew us the impropriety of the phraſe *communication of motion.* By thus reflecting on the notions that are involved in the general conception of one body being made to move by the impulſe of another, we perceive that there is nothing individual transferred from the one body to the other. The determination to motion, indeed, exiſted only in the impelling body before colliſion; whereas, afterwards, both bodies are ſo conditioned or determined. But we can form no notion of the thing transferred. With the ſame metaphyſical impropriety, we ſpeak of the communication of joy, of fever.

35
So is *vis inertiæ.*

Kepler introduced a term INERTIA VIS INERTIÆ, into mechanical philoſophy; and it is now in conſtant uſe. But writers are very careleſs and vague in the notions which they affix to theſe terms. Kepler and Newton ſeem generally to employ it for expreſſing the fact, the perſeverance of the body in its preſent ſtate of motion or reſt: but they alſo frequently expreſs by it ſomething like an indifference to motion or reſt, *manifeſted by its requiring the ſame quantity of force to make an augmentation of its motion as to make an equal diminution of it.* The popular notion is like that which we have of actual reſiſtance; and it always implies the notion of force *exerted* by the reſiſting body. We ſuppoſe this to be the exertion of the *vis inſita*, or the *inherent force* of a body in motion. But we have the ſame notion of reſiſtance from a body at reſt which we ſet in motion. Now ſurely it is in direct contradiction to the common uſe of the word *force,* when we ſuppoſe reſiſtance from a body at reſt; yet *vis inertiæ,* is a very common expreſſion. Nor is it more abſurd (and it is very abſurd) to ſay, that a body maintains its ſtate of reſt by the exertion of a *vis inertiæ,* than to ſay, that it maintains its ſtate of motion by the exertion of an *inherent force.* We ſhould avoid all ſuch metaphorical expreſſions as *reſiſtance, indifference, ſluggiſhneſs,* or *proneneſs to reſt* (which ſome expreſs by *inertia*), becauſe they ſeldom fail to make us indulge in metaphorical notions, and thus lead us to miſconceive the *modus operandi,* or procedure of nature.

There is *no reſiſtance whatever obſerved* in theſe phenomena;

Gravity is thus meaſured by the preſſure which a ſtone exerts on its ſupports. A weight which at Quito will pull out the rod of a ſpring ſteelyard to the mark 312, will pull it to 313 at Spitzbergen. And it is a fact, that a body will fall 313 inches at Spitzbergen in the ſame time that it falls 312 at Quito. Gravitation is the cauſe both of the preſſure and the fall; and it is a matter of unexcepted obſervation, that they have always the ſame ratio. The philoſophers who have ſo ſtrenuouſly maintained the other meaſure of forces, are among the moſt eminent of thoſe who have examined the motions produced by gravity, magnetiſm, electricity, &c.; and they never think of meaſuring thoſe forces any other way than by the velocity. It is in this way that the whole of the celeſtial phenomena are explained in perfect uniformity with obſervation, and that the Newtonian philoſophy is conſidered as a demonſtrative ſcience.

There muſt, therefore, be ſome defect in the principle on which the other meaſurement of forces is built, or in the method of applying it. Preſſure is undoubtedly the immediate and natural meaſure of force; yet we know that four ſprings, or a bow four times as ſtrong, give only a double velocity to an arrow.

The truth of our law reſts on this only, that we aſſume the changes of motion as the meaſure of the changing forces; or, at leaſt, as the meaſures of their exertions in producing motion. In fact, they are the meaſures only of a certain circumſtance, in which the actions of very different natural powers may reſemble each other; namely, the competency to produce motion. They do not, perhaps, meaſure their competency to produce heat, or even to bend ſprings. We can ſurely conſider this apart from all other circumſtances; and it is worthy of ſeparate conſideration. Let us ſee what can be, and what ought to be, deduced from this way of treating the ſubject.

38
Change of motion is, itſelf, a motion.

The motion of a body may certainly remain unchanged. If the direction and velocity remain the ſame, we perceive no circumſtance in which its condition, with reſpect to motion, differs. Its change of place or ſituation can make no difference; for this is implied in the very circumſtance of the bodies being in motion.

But if either the velocity or direction change, then ſurely is its mechanical condition no longer the ſame; a force has acted on it, either intrinſic or from without, either accelerating, or retarding, or deflecting it. Suppoſing the direction to remain the ſame, its difference of condition can conſiſt in nothing but its difference of velocity. This is the only circumſtance in which its condition can differ, as it paſſes through two different points of its rectilineal path. It is this determination by which the body will deſcribe a certain determinate ſpace uniformly in a given time, which defines its condition as a moving body: the changes of this determination are the meaſures of their own cauſes;—and to thoſe cauſes we have given the name *force*. Thoſe cauſes may reſide in other bodies, which may have other properties, characteriſed and meaſured by other effects. Preſſure may be one of thoſe properties, and may have its own meaſures; theſe may, or may not, have the ſame proportion with that property which is the cauſe of a change of velocity: and therefore changes of velocity may not be a meaſure of preſſure. This is a queſtion of fact, and requires obſervation and experience; but, in the mean time, velocity, and the change of velocity, is the meaſure of moving force and of changing force. When therefore the change of velocity is the ſame, whatever the previous velocity may be, the changing force muſt be conſidered as the ſame: therefore, finally, if the previous velocity is nothing, and conſequently the change on that body is the very velocity or motion that it acquires, we muſt ſay, that the force which produces a certain change in the velocity of a moving body, is the ſame with the force which would impart to a body at reſt a velocity equal to this change or difference of velocity produced on the body already in motion.

39 This manner of eſtimating force is in perfect conformity to our moſt familiar notions on theſe ſubjects. We conceive the weight or downward preſſure of a body as the cauſe of its motion downwards; and we conceive it as belonging to the body at all times, and in all places, whether falling, or riſing upwards, or deſcribing a parabola, or lying on a table; and, accordingly, we obſerve, that in every ſtate of motion it receives equal changes of velocity in the ſame, or an equal time, and all in the direction of its preſſure.

40 All that we have now ſaid of a change of velocity might be repeated of a change of direction. It is ſurely poſſible that the ſame change of direction may be made on any two motions. Let one of the motions be conſidered as growing continually ſlower, and terminating in reſt. In every inſtant of this motion it is poſſible to make one and the ſame change on it. The ſame change may therefore be made at the very inſtant that the motion is at an end. In this caſe, the change is the very motion which the body acquires from the changing force. Therefore, in this caſe alſo, we muſt ſay, that a change of motion is itſelf a motion, and that it is the motion which the force would produce in a body that was previouſly at reſt.

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meaſure

The reſult of theſe obſervations is evidently this, that we muſt aſcertain, in every inſtance, what is the change of motion, and mark it by characters that are conſpicuous and diſtinguiſhing; and this mark and meaſure of change muſt be a motion: Then we muſt ſay, that the changing force is that which would produce this motion in a body previouſly at reſt. We muſt ſee how this is manifeſt, as a motion, in the difference between the former motion and the new motion; and, on the other hand, we muſt ſee how the motion produceable in a quieſcent body may be ſo combined with a motion already exiſting, as to exhibit a new motion, in which the agency of the changing force may appear.

Suppoſe a ſhip at anchor in a ſtream; while one man walks forward on the quarter deck at the rate of two miles per hour, another walks from ſtem to ſtem at the ſame rate, a third walks athwart ſhip, and a fourth ſtands ſtill. Let the ſhip be ſuppoſed to cut or part her cable, and float down the ſtream at the rate of three miles per hour. We cannot conceive any difference in the change made on each man's motion in abſolute ſpace; but their motions are now exceedingly different from what they were: the firſt man, whom we may ſuppoſe to have been walking weſtward, is now moving eaſtward one mile per hour; the ſecond is moving eaſtward four miles per hour; and the third is moving in an oblique direction, about three points north or ſouth of due eaſt. All have ſuffered the ſame change of condition with the man who had been ſtanding ſtill. He has now got a motion eaſtward three miles per hour. In this inſtance, we ſee very well the circumſtance of ſameneſs that obtains in the change of theſe four conditions. It is the motion of the ſhip, which is blended with the other motions. But this circumſtance is equally preſent whenever the ſame previous motions are changed into the ſame new motions. We muſt learn to expiſcate this; which we ſhall do, by conſidering the manner in which the motion of the ſhip is blended with each of the mens motions.

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This kind of combination has been called the COMPOSITION OF MOTION; becauſe, in every point of the motion really purſued, the two motions are to be found.

The fundamental theorem on this ſubject is this:— Two uniform motions in the ſides of a parallelogram compoſe an uniform motion in the diagonal.

ate XXI.

Suppoſe that a point A (fig. 1.) deſcribes AB uniformly in ſome given time, while the line AB is carried uniformly along AC in the ſame time, keeping always parallel to its firſt poſition AB. The point A, by the combination of theſe motions, will deſcribe AD, the diagonal of the parallelogram ABDC, uniformly in the ſame time.

For it is plain, that the velocities in AB and AC are proportional to AB and AC, becauſe they are uniformly deſcribed in the ſame time. When the point has got to E, the middle of AB, the line AB has got into the ſituation GH, half way between AB and CD, and the point E is in the place *e*, the middle of GH. Draw E *e* L parallel to AC. It is plain, that the parallelograms ABDC and AE *e* G are ſimilar; becauſe AE and AG are the halves of AB and AC, and the angle at A is common to both. Therefore, by a propoſition in the elements, they are about the ſame diagonal, and the point *e* is in the diagonal of AD. In like manner, it may be ſhewn, that when A has deſcribed AF, ¾ths of AB, the line AB will be in the ſituation IK, ſo that AI is ¾ths of AC, and the point *f*, in which A is now found, is in the diagonal AD. It will be the ſame in whatever point of AB the deſcribing point A be ſuppoſed to be found. The line AB will be on a ſimilar point of AC, and the deſcribing point will be in the diagonal AD.

Moreover, the motion in AD is uniform: for A *e* is deſcribed in the time of deſcribing AE; that is, in half the time of deſcribing AB, or in half the time of deſcribing AD. In like manner, A *f* is deſcribed in ¾ths of the time of deſcribing AD, &c. &c.

Laſtly, the velocity in the diagonal AD is to the velocity in either of the ſides as AD is to that ſide. This is evident, becauſe they are uniformly deſcribed in the ſame time.

This is juſtly called *a compoſition of the motions* AB *and* AC, as will appear by conſidering it in the following manner: Let the lines AB AC be conceived as two material lines like wires. Let AB move uniformly from the ſituation AB into the ſituation CD, while AC moves uniformly into the ſituation BD. It is plain, that their interſection will always be found on AD. The point *e*, for example, is a point common to both lines. Conſidered as a point of EL, it is then moving in the direction *e* H or AB; and, conſidered as a point of GH, it is moving in the direction *e* L. Both of theſe motions are therefore blended in the motion of the interſection along AD. We can conceive a ſmall ring at *e*, embracing looſely both of the wires. This material ring will move in the diagonal, and *will really partake* of both motions.

Thus we ſee how the motion of the ſhip is actually blended with the motions of the three men; and the circumſtance of ſameneſs which is to be found in the four changes of motion is this motion of the ſhip, or of the man who was ſtanding ſtill. By compoſition with each of the three former motions, it produces each of the three new motions. Now, when each of two primitive motions is the ſame, and each of the new motions is the ſame, the change is ſurely the ſame. If one of the changes has been brought about by the actual compoſition of motions, we know preciſely what that change is; and this informs us what the other is, in whatever way it was produced. Hence we infer, that,

43
Its mark and meaſure.

When a motion is any how changed, the change is that motion which, when compounded with the former motion, will produce the new motion. Now, becauſe we aſſume the change as the meaſure and characteriſtic of the changing force, we muſt do ſo in the preſent inſtance; and we muſt ſay,

44
Changing force.

That *the changing force is that which will produce in a quieſcent body the motion which, by compoſition with the former motion of a body, will produce the new motion.*

And, on the other hand,

Its effect.

When the motion of a body is changed by the action of any force, the new motion is that which is compounded of the former motion, and of the motion which the force would produce in a quieſcent body.

Deflecting force.

When a force changes the direction of a motion, we ſee that its direction is tranſverſe in ſome angle BAC; becauſe a diagonal AD always ſuppoſes two ſides. As we have diſtinguiſhed any change of direction by the term DEFLECTION, we may call the tranſverſe force a DEFLECTING FORCE.

In this way of eſtimating a change of motion, all the characters of both motions are preſerved, and it expreſſes every circumſtance of the change; the mere change of direction, or the angle BAD, is not enough, becauſe the ſame force will make different angles of deflection, according to the velocity of the former motion, or according to its direction: but in this eſtimation, the full effect of the deflecting force is ſeen; it is ſeen *as a motion*; for when half of the time is elapſed, the dody is at *e* inſtead of E; when three-fourths are elapſed, it is at *f* inſtead of F; and at the end of the time it is at D inſtead of B. In ſhort, the body has moved uniformly away from the points at which it would have arrived independent of the change; and this motion has been in the ſame direction, and at the ſame rate, as if it had moved from A to C by the changing force alone. Each force has produced its full effect; for when the body is at D, it is as far from AC as if the force AC had not acted on it; and it is as far from AB as it would have been by the action of AC alone.

For all theſe reaſons, therefore, it is evident, that if we are to abide by our meaſure and character of force as a mere producer of motion, we have ſelected the proper characteriſtic and meaſure of a changing force: and our deſcriptions, in conformity to this ſelection, muſt be agreeable to the phenomena of nature, and retain the accuracy of geometrical procedure; becauſe, on the other hand, the reſults which we deduce from the ſuppoſed influence of thoſe forces are formed in the ſame mould. It is not even requiſite that the real exertions of the natural forces, ſuch as preſſure of various kinds, &c. ſhall follow theſe rules; for their deviations will be conſidered as new forces, although they are only indications of the differences of the real forces from our hypotheſis. We have obtained the precious advantage of mathematical inveſtigation, by which we can examine the law of exertion which characteriſes every force in nature.

On theſe principles we eſtabliſh the following fundamental elementary propoſition, of continual and indiſpenſable uſe in all mechanical enquiries.

45 Fundamental theorem

If a body or material particle be ſubjected at the ſame time to the action of two moving forces, each of which would ſeparately cauſe it to deſcribe the ſide of a parallelogram uniformly in a given time, the body will, deſcribe the diagonal uniformly in the ſame time.

For the body, whoſe motion AB was changed into AD, had gotten its motion by the action of ſome force. It was moving along NAB; and, when it reached the point A, the force AC acted on it. The primitive motion is the ſame, or the body is in the ſame condition in every inſtant of the primitive motion. It may have acquired this motion when it was in N, or when at O, or any other point of NA. In all theſe caſes, if AC act on it when it is in A, it will always deſcribe AD; therefore it will deſcribe AD when it acquires the primitive motion alſo in A; that is, if the two forces act on it at one and the ſame inſtant. The demonſtration may be neatly expreſſed thus: The change induced by each force on the motion produced by the other, is the motion which it would produce in the body if previouſly at reſt. Therefore the motion reſulting from joint action is the motion which is compounded of theſe two motions; or it is a motion in the diagonal of the parallelogram, of which theſe motions are the ſides.

Compoſition of forces.

This is called the Composition of Forces. The forces which produce the motions along the ſides of the parallelogram are called the Simple Forces, or the Constituent Forces; and the force which would alone produce the motion along the diagonal is called the Compound Force, the Resulting Force, the Equivalent Force.

46

On the other hand, the force which produces a motion along any line whatever, may be conceived as reſulting from the combined action of two or more forces. We may *know* or *obſerve* it to be ſo; as when we ſee a lighter dragged along a canal by two horſes, one on each ſide. Each pulls the boat directly toward himſelf in the direction of the track-rope; the boat cannot go both ways, and its real motion, whatever it is, reſults from this combined action. This might be produced by a ſingle force; for example, if the lighter be dragged along the canal by a rope from another lighter which precedes it, being dragged by one horſe, aided by the helm of the foremoſt lighter. Here the real force is not the reſulting, or the compound, but the equivalent force.

Reſolution of forces.

This view of a motion, mechanically produced, is called the Resolution of Forces. The force in the diagonal is ſaid to be *reſolved* into the two forces, having the directions and velocities repreſented by the ſides. This practice is of the moſt extenſive and multifareous uſe in all mechanical diſquiſitions. It may frequently be exceedingly difficult to manage the complication of the many real forces which concur in producing a phenomenon; and by ſubſtituting others, whoſe combined effects are equivalent, our inveſtigation may be much expedited. But more of this afterwards.

We muſt carefully remember, that when the motion AD is once begun, all compoſition is at an end, and the motion is a ſimple motion. The two determinations, by one of which the body would deſcribe AB, and by the other of which it would deſcribe AC, no longer *co-exiſt* in the body. This was the caſe only *in the inſtant*, in the very act of changing the motion AB into the motion BD; yet is the motion AD equivalent to a motion which is produced by the *actual compoſition* of two motions AB and AC; in which caſe the two motions co-exiſt in every point of AD.

47 Uſual demonſtration inconcluſive.

Accordingly this is the way in which the compoſition of forces is uſually illuſtrated, and thought to be demonſtrated. A man is ſuppoſed (for inſtance) to walk uniformly from A to C on a ſheet of ice, while the ice is carried uniformly along AB by the ſtream. The man's real motion is undoubtedly along AD; but this is by no means a demonſtration that the inſtantaneous or ſhort lived action of two forces would produce that motion; the man muſt continue to exert force in order to walk, and the ice is dragged along by the ſtream. Some indeed expreſs this proof in another way, ſaying, let a body deſcribe AB, while the ſpace in which this motion is performed is carried along AC. The ice may be carried along, and may, by friction, or otherwiſe, drag the man along with it; but a ſpace cannot be removed from one place to another, nor, if it could, would it take the man with it. Should a ſhip ſtart ſuddenly forward while a man is walking acroſs the deck, he would be left behind, and fall toward the ſtern. We muſt *ſuppoſe* a tranſverſe force, and we muſt *ſuppoſe* the compoſition of this force without proof. This is no demonſtration.

We apprehend, that the demonſtration given above of this fundamental propoſition is unexceptionable, when the terms force and deflection are uſed in the abſtract ſenſe which we have affixed to them; and we hope, by theſe means, to maintain the rigour of mathematical diſcuſſion in all our future diſquiſitions on theſe ſubjects. The only circumſtance in it which can be the ſubject of diſcuſſion is, whether we have ſelected the proper meaſure and characteriſtic of a change of motion—We never met with any objection to it.

48 Objections to the demonſtration of n° 45. It will not apply to preſſures.

But ſome have ſtill maintained, that it does not evidently appear, from theſe principles, that the motion which reſults from the joint action of two natural powers, whoſe known and meaſurable intenſities have the ſame proportions with AB and BC, and which alſo exert themſelves in thoſe directions, will produce a motion, having the direction and proportion of AD. They will not, if the velocities produced by theſe forces are not in the proportion of thoſe intenſities, but in the ſubduplicate ratio of them. Nay, they ſay, that it is not ſo. If a body be impelled along AC by one ſpring, and along AB by two ſprings equally ſtrong, it will not deſcribe the diagonal of a parallelogram, of which the ſide AB is double the ſide AC. Nay, they add, that an indefinite number of examples can be given where a body *does not* deſcribe the diagonal of the parallelogram by the joint action of two forces, which, ſeparately, would cauſe it to deſcribe the ſides. And, laſtly, they ſay, that, at any rate, it does not appear evident to the mind, that two *incitements* to motion, having the directions and the ſame proportion of intenſity with that of the ſides of a parallelogram, actually generate a third, which is the immediate cauſe of the motion in the diagonal. An equivalent force is not the ſame with a reſulting force.

49 Yet we ſee numberleſs caſes of the compoſition of incitements to motion, and they ſeem as determinate, and as ſuſceptible of being combined by compoſition, as the things called moving forces, which are meaſured by the velocities: we ſee them actually ſo combined in a thouſand inſtances, as in the example already given of a lighter dragged by two horſes pulling in different directions. Nay, experiment ſhews, that this compoſition follows preciſely the ſame rule as the compoſition of the forces which are meaſured by the velocities; for if the point A (fig. 1.) be pulled by a thread, or preſſed by a ſpring, in the direction AB, and by another in the direction AC, and if the preſſures are proportional to AB and AC, then it will be withheld from moving, if it be pulled or preſſed by a third force, acting in the direction A*d*, oppoſite to AD, the preſſure being alſo proportional to AD. This force, acting in the direction A*d*, would certainly withſtand an equal force acting in the direction AD; therefore we muſt conclude, that the two preſſures AB and AC really generate a force AD. This uniform agreement ſhews that the compoſition is deducible from fixed principles; but it does not appear that it can be held as demonſtrated by the arguments employed in the caſe of motions. A demonſtration of the compoſition of preſſures is ſtill wanted, in order to render mechanics a demonſtrative ſcience.

This com- oſition is f more dif- icult inveſ- igation.

Accordingly, philoſophers of the firſt eminence have turned their attention to this problem. It is by no means eaſy; being ſo nearly allied to firſt principles, that it muſt be difficult to find axioms of greater ſimplicity by which it may be proved.

Mechanicians generally contented themſelves with the ſolution given by Ariſtotle; but this is merely a compoſition of motions: indeed he does not give it for any thing elſe, and calls it "συνθεσις των φυ ᾳν." The firſt writer who appears to have conſidered it as different from the mere compoſition of motions, was the celebrated Dutch engineer Stevinus in his work *on Sluices;* but his ſolution is obſcure. It was ſufficient, however, to convince Daniel Bernoulli of the neceſſity and the difficulty of the problem. He has given the firſt complete demonſtration of it in the firſt volume of the Commentaries of the Imperial Academy of Sciences at St Peterſburgh. It is extremely ingenious; but it is tedious and intricate, requiring a ſeries of 15 propoſitions to demonſtrate that two preſſures, having the directions and magnitudes of the ſides of any parallelogram, compoſe a third, which has the direction and magnitude of its diagonal. His firſt propoſition is, that *two equal preſſures, acting at right angles, compoſe a third, in the direction of the diagonal of a ſquare, and having to either of the other two the proportion of the diagonal of a ſquare to its ſides.*

Mr D'Alembert has greatly ſimplified and improved this demonſtration, by beginning with a caſe that is ſelf-evident; namely, *If three equal forces are inclined to each other in equal angles of 120 degrees, any one of them will balance the combined action of the other two.* Surely; for neither of them can prevail. Therefore *two* equal forces, inclined in an angle of 120 degrees, produce a third, which has the direction and proportion of the diagonal of the rhombus; for this is equal and oppoſite to one of the three above mentioned. He then demonſtrates the ſame thing of two equal forces inclined in *any* angle; and by a ſeries of eight propoſitions more, demonſtrates the general theorem. This diſſertation is in the Memoirs of the Academy at Paris for 1769. He improves it ſtill farther in a ſubſequent memoir.

Mr Riccati and Mr Fonſenex, in the Commentaries of the Academy of Turin, have given analytical demonſtrations, which are alſo very ingenious and conciſe, but require acquaintance with the higher methematics.—There is another very ingenious demonſtration in the *Journal des Sçavans* for June 1764, but too obſcure for an elementary propoſition. It is ſomewhat ſimplified by Belidor in his *Ingenieur François*. Friſius, in his *Coſmographia*, has given one, which is perhaps the beſt of all thoſe that are eaſily comprehended without acquaintance with the higher mathematics: but we imagine that, although no one can doubt of the concluſion, it has not that intuitive evidence for every ſtep of the proceſs that ſeems neceſſary.

50 *Compoſition of preſſures.*

We here offer another, compoſed by blending together the methods of Bernoulli and D'Alembert; and we imagine that no objection can be made to any ſtep of it. We limit it entirely to preſſures, and do not at all conſider nor employ the motions which they may be ſuppoſed to produce.

(A) If two equal and oppoſite preſſures or incitements to motion act at once on a material particle, it ſuffers no change of motion; for if it yields in either direction by their joint action, one of the preſſures prevails, and they are not equal.

Equal and oppoſite preſſures are ſaid TO BALANCE each other; and ſuch as balance muſt be eſteemed equal and oppoſite.

(B) If a and b are two magnitudes of the ſame kind, proportional to the intenſities of two preſſures which act in the ſame direction, then the magnitude $a+b$ will meaſure the intenſity of the preſſure, which is equivalent, and may be called equal, to the combined effort of the other two; for when we try to form a notion of preſſure as a meaſurable magnitude, diſtinct from motion or any other effect of it, we find nothing that we can meaſure it by but another preſſure. Nor have we any notion of a double or triple preſſure different from a preſſure that is equivalent to the joint effort of two or three equal preſſures. A preſſure a is accounted triple of a preſſure b, if it balances three preſſures, each equal to b, acting together. Therefore, in all proportions which can be expreſſed by numbers, we muſt acknowledge the legitimacy of this meaſurement; and it would ſurely be effectation to omit thoſe which the mathematicians call *incommenſurable*.

In like manner, the magnitude $a-b$ muſt be acknowledged to meaſure that preſſure which ariſes from the joint action of two preſſures a and b acting in oppoſite directions, of which a is the greateſt.

(C) Let ABCD and A*b* C*d* (fig. A) be two rhombuſes, which have the common diagonal AC. Let the angles BA*b*, DA*d*, be biſected by the ſtraight lines AE and AF.

If there be drawn from the points E and F the lines EG, EH, F*g*, F*h*, making equal angles on each ſide of EA and FA, and if G*g*, H*h* be drawn, cutting the diagonal AC in I and L: then AI + AL will be greater or leſs than AQ, the half of AC, according as the angles GEH, *g*F*h*, are greater or leſs than GAH, *g*A*h*.

Draw GH, *gh*, cutting AE, AF, in O and *o*, and draw O*o*, cutting AC in K.

Becauſe the angles AEG and EAG are reſpectively equal to AEH and EAH, and AE is common to both triangles, the ſides AG, GE are reſpectively equal to AH, HE, and GH is perpendicular to AE, and is biſected in O; for the ſame reaſons, *gh* is biſected in *o*. Therefore the lines G*g*, O*o*, H*h*, are parallel, and IL is biſected in K. Therefore AI+AL is equal to twice AK. Moreover, if the angle GEH be greater than GAH, AO is greater than EO, and AK is greater than KQ. Therefore AI+AL is greater than AQ; and if the angle GEH be leſs than GAH, AI+AL is leſs than AQ.

(D) Two equal preſſures, acting in the directions AB and AC (fig. 2.), at right angles to each other, compoſe a preſſure in the direction AD, which biſects the right angle; and its intenſity is to the intenſity of each of the conſtituent preſſures as the diagonal of a ſquare to one of the ſides. It is evident, that the direction of the preſſure, generated by their joint action, will biſect the angle formed by their directions; becauſe no reaſon can be aſſigned for the direction inclining more to one ſide than to the other.

In the next place, ſince a force in the direction AD does, in fact, ariſe from the joint action of the equal preſſures AB and AC, the preſſure AB may be conceived as ariſing from the joint action of two equal forces ſimilarly inclined and proportioned to it. Draw EAF perpendicular to AD. One of theſe forces muſt be directed along AD, and the other along AE. In like manner, the preſſure AC may ariſe from the joint action of a preſſure in the direction AD, and an equal preſſure in the direction AF. It is alſo plain, that the preſſures in the directions AE and AF, and the two preſſures in the direction AD, muſt be all equal. And alſo, any one of them muſt have the ſame proportion to AB or to AC, that AB or AC, has to the force in the direction AD, ariſing from their joint action.

Therefore, if it be ſaid that AD does not meaſure the preſſure ariſing from the joint action of AB and AC, let A *d*, greater than AD, be its juſt meaſure, and make A *d*: AB = AB : A*g* = AB : A *e*. Then A*g* and A *e* have the ſame inclination and proportion to AB that AB and AC have to A *d*. We determine, in like manner, two forces A *f* and A *g* as conſtituents of AC.

Now A *d* is equivalent to AB and AC, and AB is equivalent to A *e* and A*g*; and AC is equivalent to A *f* and A*g*. Therefore A *d* is equivalent to A *e*, A *f*, A *g*, and A *g*. But (A) A *e* and A *f* balance each other, or annihilate each other's effect; and there remain only the two forces or preſſures A*g*, A*g*. Therefore (B) their meaſure is a magnitude equal to twice A*g*. But if A *d* be greater than the diagonal AD of the ſquare, whoſe ſides are AB and AC; then A*g* muſt be leſs than AI, the ſide of the ſquare whoſe diagonal is AB. But twice A*g* is leſs than AD, and much leſs than A *d*. Therefore the meaſure of the eqivalent of AB and AC cannot be a line A *d* greater than AD. In like manner, it cannot be a line A *δ* that is leſs than AD. Therefore it muſt be equal to AD, and the propoſition is demonſtrated.

(E) *Cor.* Two equal forces AB, AC, acting at right angles, will be balanced by a force AO, equal and oppoſite to AD, the diagonal of the ſquare whoſe ſides are AB and AC; for AO would balance AD, which is the equivalent of AB and AC.

(F) Let AECF (fig. 3.) be a rhombus, the acute angle of which EAF is half of a right angle. Two equal preſſures, which have the directions and meaſures AE, AF, compoſe a preſſure, having the direction and meaſure AC, which is the diagonal of the rhombus.

It is evident, in the firſt place, that the compound force has the direction AC, which biſects the angle EAF. If AC be not its juſt meaſure, let it be AP leſs than AC. Let ABCD be a ſquare diſcribed on the ſame diagonal, and make AP : AQ = AE : AO, = AF : A*o*. Draw KOG, K *o g* perpendicular to AE, AF; draw G I *g*, OH *o*, EG, EK, F*g*, FK, PF, and PE.

The angles CAB and FAE are equal, each being half of a right angle. Alſo the figures AEPF and AGEK are ſimilar, becauſe AP : AQ = AE : AO. Therefore FA : AP = KA : AE, and EA : AP = GA : AE. Therefore, in the ſame manner that the forces AE, AF are affirmed to compoſe AP, the forces AG and AK may compoſe the force AE, and the forces A *g* and AK may compoſe the force AF. Therefore (B) the force AP is equivalent to the four forces AG, AK, A *g*, AK. But (D) AG and A*g* are the ſides of a ſquare, whoſe diagonal is equal to twice AI: and the two forces AK, AK are equal to, or are meaſured by, twice AK. Therefore the four forces AG, AK, A *g*, AK, are equivalent to 2 AI + 2 AK, = 4 AH.

But becauſe AP was ſuppoſed leſs than AC, the angle FPE is greater than FAE, and GEK is greater than GAK, AO is greater than OE, and AH is greater than HQ, and 2 AH is greater than AQ; and therefore 4 AH is greater than AC, and much greater than AP. Therefore AP is not the juſt meaſure of the force compoſed of AE and AF.

In like manner, it is ſhewn, that AE and AF do not compoſe a force whoſe meaſure is greater than AC. It is therefore equal to AC; and the propoſition is demonſtrated.

(G) By the ſame proceſs it may be demonſtrated, that if BAD be half a right angle, and EAF be the fourth of a right angle, two forces AE, AF will compoſe a force meaſured by AC. And the proceſs may be repeated for a rhombus whoſe acute angle is $\frac{1}{8}$th, $\frac{1}{16}$th, &c. of a right angle; that is, any portion of a right angle that is produced by continual biſection. Two forces, forming the ſides of ſuch a rhombus, compoſe a force meaſured by the diagonal.

(H) Let ABCD, A *b c d* (fig. 4.) be two rhombuſes formed by two conſecutive biſections of a right angle. Let AECF be another rhombus, whoſe ſides AE and AF biſect the angles BA *b* and DA *d*.

The

neceſſary to inveſtigate the laws of combined preſſure as we did the laws of combined motion in conſequence of preſſure. Yet we ſhould err, if we haſtily aſſerted that preſſures are not proportional to the motions which they produce; all that we are intitled to call in doubt is, whether the preſſures in their exertion, while they actually produce motion, or changes of motion, continue to be the ſame as when they do not produce motion, being withſtood or balanced by oppoſite preſſures. Conſidered as cauſes of motion, we ought to think that they do not vary while they produce motion, and that the actual preſſure, while it produces a double motion, is really double, although it may be quadruple when the body exerting it is made to act on a body that it cannot move. We are confirmed in this opinion by obſerving, that other facts ſhew us, that even while producing motion, the preſſure which we call quadruple, becauſe we have meaſured it by four equal preſſures balancing it, is really quadruple, conſidered as the cauſe of motion, and produces a quadruple motion. A bow which requires four times the force to draw it to any given extent, will communicate the ſame velocity to a bundle of four arrows that a bow four times eaſier drawn communicates to one arrow, and will therefore produce a quadruple motion. Yet it will only produce a double velocity in the arrow that acquired a ſimple velocity from a bow having one fourth of the ſtrength.

Theſe diſcrepancies ſhould excite the endeavours of mechanicians to inveſtigate the laws obſerved in the action of preſſures in producing motion. Had this been done with care and with candour, we ſhould not have had the great difference of opinion, which ſtill divides philoſophers, about the meaſures of moving forces. But a ſpirit of party, which had ariſen from other cauſes, gave importance to what was at firſt only a difference of expreſſion, and made the partiſans of Mr Leibnitz avail themſelves of the figurative language which has done ſo much harm in all the departments of philoſophy. Notwithſtanding all our caution, it is hardly poſſible to avoid metaphorical conceptions when we employ the language of metaphor. The abettors of the Leibnitzian meaſure of moving forces, or perhaps, to ſpeak more properly, the abettors of the Leibnitzian meaſure of that force which is ſuppoſed to preſerve bodies in their condition of motion—inſiſt, that the force which is exerted in producing any change of motion is greater in proportion as the motion changed is greater: and they give a very ſpecious argument for their aſſertion. They appeal to the exertions which we ourſelves make. Here we are conſcious of the fact. Then they give ſimilar examples of the action of bodies. A clay ball, moving ſix feet per ſecond, will make the addition of one foot to the velocity of an equal clay ball that is already moving four feet per ſecond in the ſame direction. But if this laſt ball be already moving ten feet per ſecond, we muſt follow it with a velocity of twelve feet in order to increaſe its velocity one foot. But, without inſiſting on the numberleſs paralogiſms and inconſiſtencies which this way of conceiving the matter would lead us into, it ſuffices to obſerve, that the phenomena give us abundant aſſurance that there has been the ſame exertion in both theſe caſes. This acceleration is always accompanied by a compreſſion of the balls, and the compreſſion is the ſame in both. This compreſſion is a very good meaſure of the force employed to produce it; and in the preſent caſe, we need not even trouble ourſelves with any rule for its meaſurement: for ſurely when the compreſſion is not different, but the ſame, the force exerted is the ſame. This is farther confirmed by obſerving, that it requires the ſame force to make the ſame pit, or to give the ſame motion, to a piece of clay, lying on the table of a ſhip's cabin, whether the ſhip be ſailing two miles or ten miles per hour.

Thus we ſee that there are ſtrong reaſons for believing, that the exertions of preſſure in producing motion, or that the preſſures *actually exerted*, are proportional to the changes of motion obſerved, and that they coincide in this reſpect with our abſtract conceptions of moving forces.

But we have ſtill better arguments. None of the Leibnitzians think of denying the equal exertions of gravity, or of any of thoſe powers which they call *ſolicitations* or *accelerating forces*. They all admit, that gravity, or any conſtant accelerating force, produces equal increments of velocity in equal times, and that a double gravity will produce a double increment in an equal time, and an equal increment in half of the time; and that a quadruple gravity will produce a double velocity in half the time. All theſe things are granted by them, and their writings are full of reaſonings from this principle. Now from the fact, acknowledged by the Leibnitzians, that the quadruple force of a bow gives a double velocity to the arrow, in every inſtant of its action, it indiſputably follows, that it has acted on it only for half the time of the action of the four times weaker bow, which gives the arrow only half the velocity; and thus has the diſcrepancy between the effects of preſſures and of our abſtract moving forces entirely diſappeared. For this circumſtance of the difference in the time of acting will be found, on ſtrict examination, in all the caſes of the change of motion by preſſures which we meaſure by their effects on a body at reſt. When this, and the appreciable changes of actual preſſure, during the time of producing the motion, are taken into conſideration, all difference vaniſhes, and the compoſition of preſſures is in perfect harmony with the compoſition of motions, or of abſtract moving forces. Dynaimcs is thus made a demonſtrative ſcience, and affords the opportunity of inveſtigating, by obſervation and experiment, the nature of thoſe mechanical powers which reſide in bodies, and which appear to us under the form of preſſure, inducing us to conſider preſſure as a cauſe of motion.

In this, however, we are rather inaccurate. Preſſure is one of the ſenſible effects of that property which is alſo the cauſe of motion. It is not the preſſure of a piece of lead, but its heavineſs, that is the reaſon that it gives motion to a kitchen jack. Preſſure is merely a generic name, borrowed from a familiar inſtance, and given to moving forces, which have the ſame nature, but different names that ſerve to mark their connection with certain ſubſtances, in which they may be ſuppoſed to reſide. Natural philoſophy is almoſt entirely employed in examining the nature of theſe various preſſures or accelerative forces; and the general doctrines of dynamics, by aſcertaining what is common to them all, enable us to mark with preciſion what is characteriſtic of each.

53 General corollaries.

We have now advanced very far in this inveſtigation;

DENDROMETER, PLATE XXI.

Fig. 1.

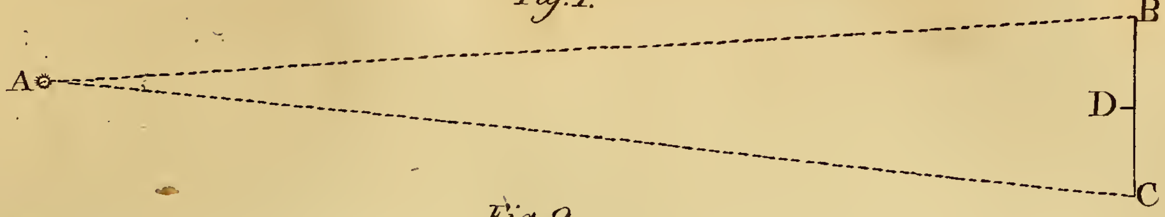


Fig. 2.

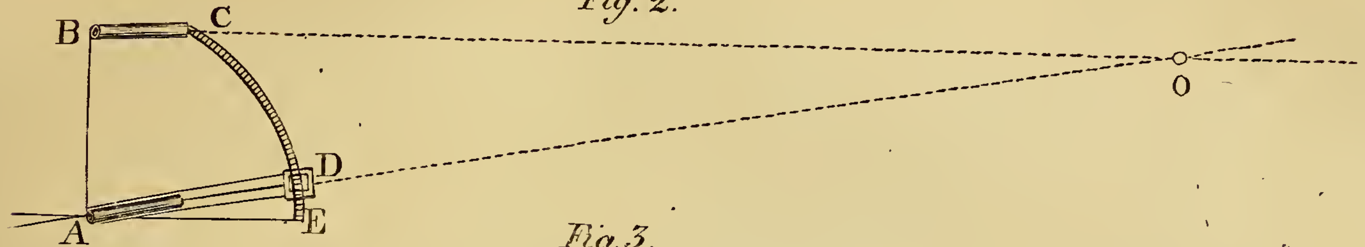
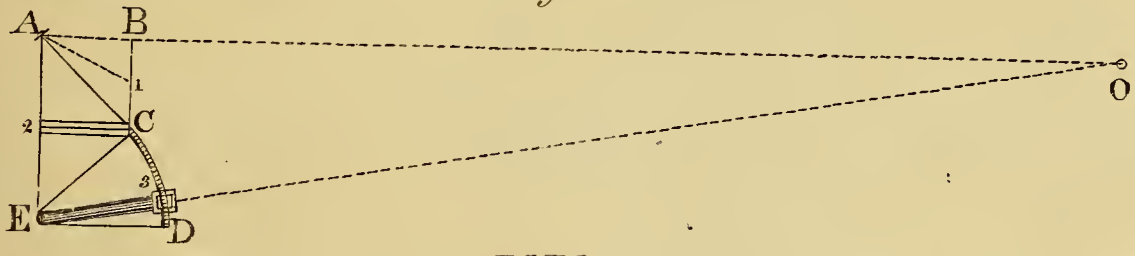


Fig. 3.



DYNAMICS.

Fig. 3.

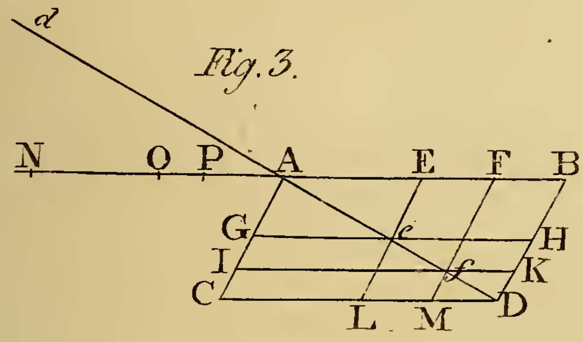


Fig. A.

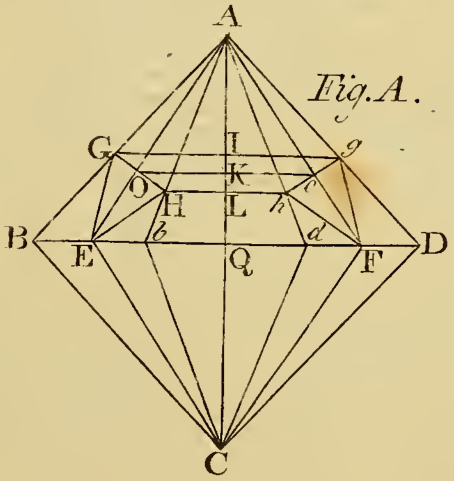
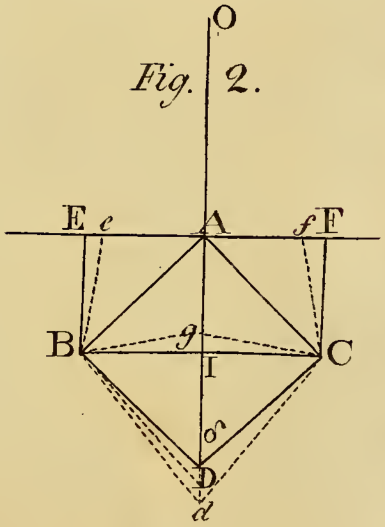


Fig. 2.



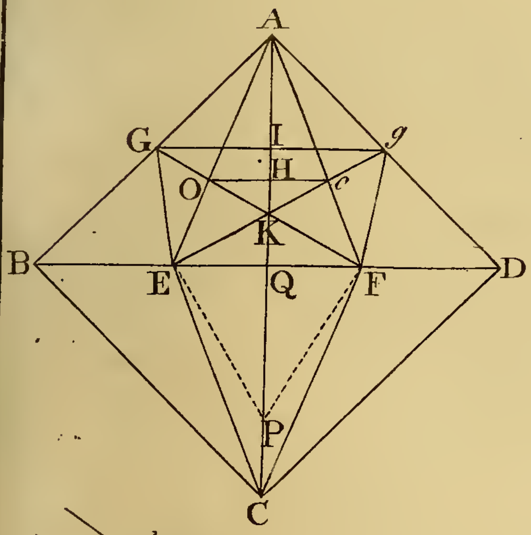


Fig. 5.

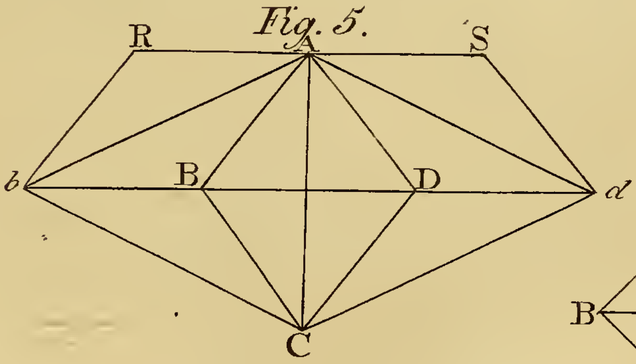
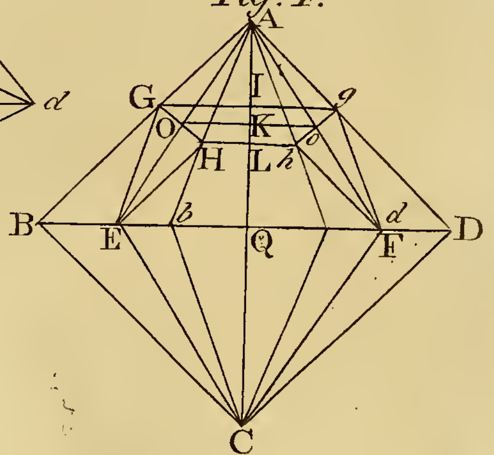


Fig. 4.



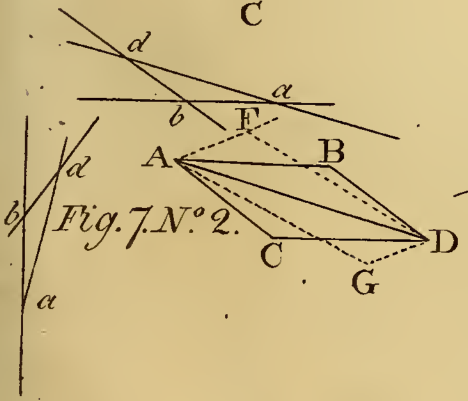


Fig. 7. N.° 2.

Fig. 6.

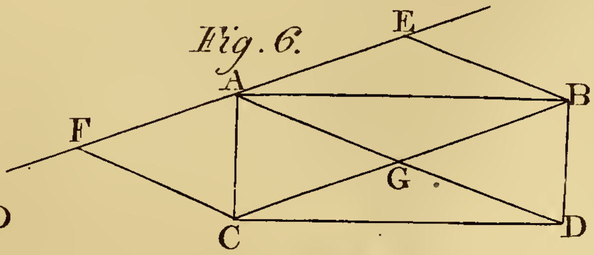
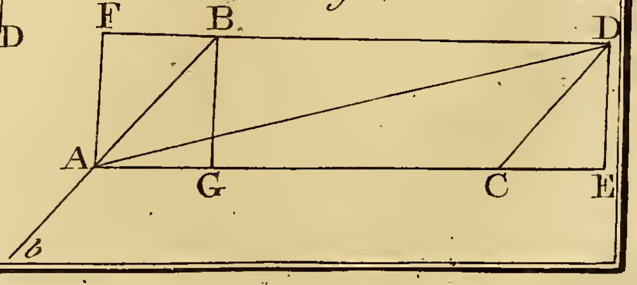


Fig. 7.



for we have obtained the criterion by which we learn the direction and the magnitude of every changing force: and, on the other hand, we ſee how to ſtate what will be the effect of the exertion of any force that is known or ſuſpected to act. All this we learn by the compoſition of forces; and the greateſt part of mechanical diſquiſition conſiſts in the application of this doctrine. For ſuch reaſons it merits minute conſideration; and therefore we muſt point out ſome general concluſions from the properties of figure, which will greatly facilitate the uſe of the parallelogram of forces.

54 1. The conſtituent and the reſulting forces, or the ſimple and compound forces, act in the ſame plane; for the ſides and diagonal of a parallelogram are in one plane.

55 2. The ſimple and the compound forces are proportional to the ſides of any triangle which are parallel to their directions. For if any three lines, *ab, bd, ad,* be drawn parallel to AB, AC, and AD (fig. 7, n° 2.), they will form a triangle ſimilar to the triangle ABD. For the ſame reaſons they are proportional to the ſides of a triangle *a′b′d*, which are reſpectively perpendicular to their directions.

56 3. Therefore each is proportional to the ſine of the oppoſite angle of this triangle; for the ſides of any triangle are proportional to the ſines of the oppoſite angles.

57 4. Each is proportional to the ſine of the angle contained by the directions of the other two; for AD is to AB as the ſine of the angle ABD to the ſine of the angle ADB. Now the ſine of ABD is the ſame with the ſine of BAC contained between the directions AB and AC, and the ſine of ADB is the ſame with the ſine of CAD; alſo AB is to AC, or BD, as the ſine of ADB (or CAD) to the ſine of BAD.

58
Some ſpecial uſes of the parallelogram of forces.

We now proceed to the application of this fundamental propoſition. And we obſerve, in the firſt place, that ſince AD may be the diagonal of an indefinite number of parallelograms, the motion or the preſſure AD may reſult from the joint action of many pairs of forces. It may be produced by forces which would ſeparately produce the motions AF and AG. This generally gives us the means of diſcovering the forces which concur in its production. If one of them, AB, is known in direction and intenſity, the direction AC, parallel to BD, and the intenſity, are diſcovered. Sometimes we know the directions of both. Then, by drawing the parallelogram or triangle, we learn their proportions. The force which deflects any motion AB into a motion AD, is had by ſimply drawing a line from the point B (to which the body would have moved from A, in the time of really moving from A to D) to the point D. The deflecting force is ſuch as would have cauſed the body move from B to D in the ſame time. And, in the ſame manner, we get the compound motion AD, which ariſes from any two ſimple motions AB and AC, by ſuppoſing both of the motions to be accompliſhed in ſucceſſion. The final place of the body is the ſame, whether it moves along AD or along AB and BD in ſucceſſion.

59
Equivalent of many forces.

This theorem is not limited to the compoſition of two motions or two forces only; for ſince the combined action of two forces puts the body into the ſame ſtate as if their equivalent alone had acted on it, we may ſuppoſe this to have been the caſe, and then the action of a third force will produce a change on this equivalent motion. The reſulting motion will be the ſame as if only this third force and the equivalent of the other two had acted on the body. Thus, in fig. 8. the three forces AB, AC, AE, may act at once on a particle of matter. Plate XXII. Complete the parallelogram ABDC; the diagonal AD is the force which is generated by AB and AC. Complete the parallelogram AEFD; the diagonal AF is the force reſulting from the combined action of the forces AB, AC, and AE. In like manner, completing the parallelogram AGHF, the diagonal AH is the force reſulting from the combined action of AB, AC, AE, and AG, and ſo on of any number of forces.

This reſulting force and the reſulting motion may be much more expeditiouſly determined, in any degree of compoſition, by drawing lines in the proportion and direction of the forces in ſucceſſion, each from the end of the preceding. Thus, draw AB, BD, DF, FH, and join AH; AH is the reſulting force. The demonſtration is evident.

60 It is to be noticed here, that in the compoſition of more than two forces, we are not limited to one plane. The force AD is in the ſame plane with AB and AC; but AE may be elevated above this plane, and AG may lead below it. AF is in the plane of AD and AE, and AH is in the plane of AF and AG.

Complete the parallelograms ABLE, ACKE, ELFK. It is evident that ABLFKCD is a parallelopiped, and that AF is one of its diagonals. Hence we derive a more general theorem of great uſe.

Three forces having the proportion and direction of the three ſides of a parallelopiped, compoſe a force having the proportion and direction of the diagonal.

61
One force may balance many acting together.

Any number of forces acting together on one particle of matter are balanced by a force that is equal and oppoſite to their reſulting force; for this force would balance their reſulting force which is equivalent to them in action. When this is duly conſidered, we perceive that each force is then in equilibrio with the equivalent of all the others; for a force can balance only what is equal and oppoſite to it. It appears very readily by the geometrical conſtruction. If, inſtead of the circuit A, B, D, F, H, we take B, D, F, H, A, we have BA for the equivalent of the forces AC, AE, AG; but AB is equal and oppoſite to BA. Therefore the force AB is in equilibrio with the equivalent of all the others.

62 When any number of forces act on one particle of matter, and are in equilibrio, if they be conſidered as acting in parcels, the equivalents of theſe parcels are in equilibrio: for let the forces AB, AC, AE, AG, A*h*, be in equilibrio, and let them be conſidered in the two parcels AB, AC, and AE, AG, A*h*; then AD is the equivalent of AB, BD (or AC), and DA is the equivalent of DF, FH, HA (or A *h*): now AD and DA balance each other. This corrollary enables us to ſimplify many intricate complications of force; it alſo enables us to draw accurate concluſions from very imperfect obſervations. In moſt of our practical diſcuſſions we know, or at leaſt we attend to, a part only of the forces which are acting on a material particle; and in ſuch caſes we reaſon as if we ſaw the whole: yet is our mathematical reaſoning good with reſpect to the equivalent of all the parcels which we are contemplating, and the equivalents of the ſmaller parcels of which it

conſiſts; and the neglected force, or parcel of forces, induces no error on our concluſions.

63 Expeditious methods for obtaining the reſulting motion in complicated caſes.

In the ſpontaneous phenomena of nature, the inveſtigation and diſcovery of our ultimate object of ſearch is frequently very difficult, on account of the multiplicity of directions and intenſities of the operating forces or motions. We may generally facilitate the proceſs, by ſubſtituting equivalent forces or motions acting in convenient directions. It is in this way that the navigator computes the ſhip's place with very little trouble, by ſubſtituting equivalent motions in the meridional and equatorial directions for the real oblique courſes of the ſhip. Inſtead of ſetting down ten miles on a courſe, S. 36. 52. W. he ſuppoſes that the ſhip has ſailed eight miles due ſouth, and ſix miles due weſt, which brings her near to the ſame place. Then, inſtead of fourteen miles ſouth-weſt, he ſets down ten miles ſouth and ten miles weſt; and he proceeds in the ſame way for every other courſe and diſtance. He does this expeditiouſly by means of a traverſe table, in which are ready calculated the meridional and equatoreal ſides of right angled triangles, correſponding to every courſe and diſtance. Having done this for the courſe of a whole day, he adds all the ſouthings into one ſum, and all the weſtings into another: he conſiders theſe as forming the ſides of a right angled triangle; he looks for them, paired together, in his traverſe table, and then notices what angle and what diſtance correſponds to this pair. This gives him the poſition and magnitude of the ſtraight line joining the beginning and end of his day's work.

The miner proceeds in the ſame way when he takes the plan of ſubterraneous workings, meaſuring, as he goes along, and noticing the bearing of each line by the compaſs, and ſetting down, from his traverſe table, the northing or ſouthing, and the eaſting or weſting, for each oblique line: but there is another circumſtance which he muſt attend to, namely, the ſlope of the various drifts, galleries, and other workings. This he does by noting the riſe or the dip of each ſloping line. He adds all theſe into two ſums, and taking the riſings from the dips, he obtains the whole dip. Thus he learns how far the workings proceed to the noth, how far to the eaſt, and how far to the dip.

The reflecting reader will perceive that the line joining the two extremities of this progreſſion will form the diagonal of a rectangular parallelopiped; one of whoſe ſides lies north and ſouth, the other lies eaſt and weſt, and the third is right up and down.

The mechanician proceeds in the very ſame way in the inveſtigation of the very complicated phenomena which frequently engage his attention. He conſiders every motion as compounded of three motions in ſome convenient directions, at right angles to each other. He alſo conſiders every force as reſulting from the joint action of three forces, at right angles to each other, and takes the ſum or difference of theſe in the ſame or oppoſite directions. From this proceſs he obtains the three ſides of a parallelopiped, and from theſe computes the poſition and magnitude of the diagonal. This is the motion or force reſulting from the compoſition of all the partial ones.

Forces may be eſtimated by, or reduced to,

This procedure is called the ESTIMATION or REDUCTION of motions and forces.

A motion or force AB (fig. 9.) is ſaid to be *eſtimated* in the direction EF, or to be *reduced* to this direction when it is conceived as compounded of the motions or forces AC, AD, one of which AC is parallel to EF, and the other AD is perpendicular to it. This expreſſion is abundantly ſignificant; for it is plain that the motion AD neither promotes nor hinders the progreſs along EF, and that AC expreſſes the whole progreſs in this direction.

64 A given direction,

65 Or a given plane.

In like mannar, a force AB (fig. 10.) is ſaid to be *eſtimated in* or *reduced to*, a given plane EFGH, when it is conceived as reſulting from the joint action of two forces AC, AD, one of which is parallel to a line *a b* drawn in that plane, and the other AD is perpendicular to it. The poſition of the line *a b* is determined by letting fall B *b* perpendicular to the plane, and drawing *b* P to the point P, in which BA meets the plane; then A *a* being drawn parallel to B *b*, will cut off *b a*, which is the reduction of the motion AB to the plane. Drawing AC parallel to *a b*, and completing the parallelogram ACBD, it is evident that the motion AB is equivalent to AD and AC, which is parallel to *a b*, and the three forces AB, AC, AD, are, as they ſhould be, in one plane perpendicular to the plane EG.

66 Equilibrium of forces ſo eſtimated or reduced.

If three forces AB, AC, AD (fig. 11.), are in equilibrio, and are reduced to any one direction *d* A *l*, or to one plane EFGH, the reduced forces are alſo in equilibrio.

Firſt, Let them be reduced to one direction *d l* by drawing the perpendiculars B *b*, C *c*, D *d*; make AL equal to AD, and join BL, CL, and draw the perpendiculars L *l*, C *c*; then, becauſe the forces AB, AC, AD, are in equilibrio, ABLC muſt be a parallelogram, and AL is the force equivalent to AB and AC combined; then, becauſe the lines D *d*, B *b*, C *c*, L *l*, are parallel, *d* A is equal to A *l*, and A *b* to C *o*, or to *c l*; therefore A *l* is equal to the ſum of A *b* and A *c*, which are the reductions of AB and AC; therefore *d* A is equal to the ſame ſum, and in equilibrio with them.

Secondly, Let them be reduced to one plane EFGH, and let $\alpha\beta$, $\alpha\kappa$, $\alpha\delta$, be the reduced forces. The lines Dδ, Aα, Bβ, Cκ, Lλ, are all parallel, being perpendicular to the plane; therefore the planes AB$\beta\alpha$ and CL$\lambda\kappa$ are parallel, and $\alpha\beta$, $\kappa\lambda$, are parallel. For ſimilar reaſons $\beta\lambda$, $\alpha\kappa$, are parallel; therefore $\alpha\beta\lambda\kappa$ is a parallelogram. Alſo, becauſe the lines Dδ, Aα, Lλ, are parallel, and DA is equal to AL; therefore $\delta\alpha$ is equal to $\alpha\lambda$. But becauſe $\alpha\beta\lambda\kappa$ is a parallelogram, the forces $\alpha\beta$, $\alpha\kappa$, are equivalent to $\alpha\lambda$; and $\alpha\delta$ is equal and oppoſite to $\alpha\lambda$, and will balance it; and therefore will balance $\alpha\beta$ and $\alpha\kappa$, which are the reductions of AB and AC to the plane EFGH, while $\alpha\delta$ is the reduction of AD; therefore the propoſition is demonſtrated.

The moſt uſeful mode of reduction to their co-ordinates.

The moſt uſual and the moſt uſeful mode of reduction, is to eſtimate all forces in the directions of three lines drawn from one point, at right angles to each other, like the three plane angles of a rectangular cheſt, forming the length, the breadth, and the depth of the cheſt. Theſe are commonly called the three co-ordinates. The reſulting force will be the diagonal of this parallelopiped. This proceſs occurs in all diſquiſitions in which the mutual action of ſolids and fluids is conſidered, and when the oſcillation or rotation of detached free bodies is the ſubject of diſcuſſion.

The only other general theorem that remains to be deduced

67
Relative motions of bodies not affected by any extraneous equal and parallel force.

deduced from this law of motion is, that if a number of bodies are moving in any manner whatever, and an equal force act on every particle of matter in the ſame or parallel directions, their relative motions will ſuffer no change; for the motion of any body A (fig. 12.), relative to another body B, which is alſo in motion, is compounded of the real motion of A, and the oppoſite to the real motion of B; for let A move uniformly from A to C, while B deſcribes BD uniformly, draw AB, alſo draw AE equal and parallel to BD, join EC, DC, ED. The motion of A, relative to B, conſiſts in its change of poſition and diſtance. Had A deſcribed AE, while B deſcribed BD, there would have been no change of relative place or diſtance; but A is now at C, and DC is its new direction and diſtance. The relative or apparent motion of A therefore is EC. Complete the parallelogram ACFE; it is plain that the motion EC is compounded of EF, which is equal and parallel to AC, the real motion of A, and of EA, the equal and oppoſite to BD, the real motion of B.

Now let the motions of A and B ſuſtain the ſame change; let the equal and parallel motions AG, BH, be compounded with the motions AC and BD; or let forces act at once on A and B, in the parallel directions AG, BH, and with equal intenſities; in either ſuppoſition, the reſulting motions will be A *c*, B *d*, the diagonals of the parallelograms A G *c* C, and B H *d* D. Conſtruct the figure as before, and we ſee that the relative motion is now *e c*, and that it is the ſame with EC both in reſpect of magnitude and poſition.

Here we ſtill ſee the conſtant analogy between the compoſition of motions and the compoſition of forces. In the firſt caſe, the relative motions of things are not changed, whatever common motion be compounded with them all; or, as it is uſually, but inaccurately, expreſſed, although the ſpace in which they move be carried along with any motion whatever. In the ſecond caſe, the relative motions and actions are not changed by any external force, however great, when equally exerted on every particle in parallel directions.

Thus it is that the evolutions of a fleet in a uniform current are the ſame, and produced by the ſame means, as in ſtill water. Thus it is that we walk about on the ſurface of this globe in the ſame manner as if it neither revolved round the ſun, nor turned round its axis. Thus it is that the ſame ſtrength of a bow will communicate a certain velocity to an arrow, whether it is ſhot eaſt, or weſt, or north, or ſouth. Thus it is that the mutual actions of ſublunary bodies are the ſame, in whatever directions they are exerted, and notwithſtanding the very great changes in their velocities by reaſon of the earth's rotation and orbital revolution. The real velocity of a body on the earth's equator is about 3000 feet per ſecond greater at midnight than at midday. For at midnight the motion of rotation nearly conſpires with the orbital motion, and at midday it nearly oppoſes it. The difference between the velocities at the beginning of January and the beginning of July is vaſtly greater. And at other times of the day, and other ſeaſons of the year, both motions of the earth are tranſverſely compounded with the eaſterly or weſterly motion of an arrow or cannon bullet. Yet we can obſerve no change in the effects of the mutual actions of bodies.

68
This affords a demonſtration of the proportionality of moving forces to the motions produced by them,

This is an important obſervation; becauſe it proves that forces are to be meaſured by no other ſcale than by the motions which they produce. We have had repeated occaſions to mention the very different eſtimation of moving forces by Mr Leibnitz; and have ſhewn how, by a very partial conſideration of the action of thoſe natural powers called *preſſures*, he has attempted to prove, that moving forces are proportional to the ſquares of the velocities; and we ſhewed briefly, in what manner a right conſideration of what paſſes when motion is produced by meaſurable preſſures, proves that the forces really exerted are as the velocities produced. But the moſt copious proof is had from the preſent obſervation, that, in fact, the mutual actions of bodies depend on their relative motions alone.

69
And is incompatible with their proportionality to the ſquares of thoſe motions.

The Leibnitzian meaſure of moving force is altogether incompatible with the univerſal fact now mentioned, *viz.* that the relative motions of bodies, reſulting from their mutual actions, are not affected by any common motion, or the action of any equal and parallel force on both bodies: for this univerſal fact imports, that when two bodies are moving with equal velocities in the ſame direction, a force applied to one of them, ſo as to increaſe its velocity, gives it the ſame motion relative to the other, as if both bodies had been at reſt. Here it is plain, that the ſpace deſcribed by the body in conſequence of the primitive force, and of the force now added, is the ſum of the ſpaces which each of them would generate in a body at reſt. Therefore the forces are proportional to the velocities or changes of motion which they produce, and not to the ſquares of thoſe velocities. This meaſure of forces, or the poſition that a force makes the ſame change on any velocity whatever, and the independence of the relative motions on any motion that is the ſame on all the bodies of a ſyſtem, are counterparts of each other. Since this independence is a matter of obſervation in all terreſtrial bodies, we are intitled to ſay, that the powers which the Author of Nature has imparted to natural bodies are no way different from what are competent to matter once called into exiſtence. And it alſo follows from this, that we muſt always remain ignorant of the abſolute motions of bodies. The fact, that it has required the unremitted ſtudy of ages to diſcover even the relative motions of our ſolar ſyſtem, is an argument to prove that the influence of this mechanical principle extends far beyond the limits of this ſublunary world; nor has any phenomenon yet been exhibited which ſhould lead us to imagine that it is not univerſal.

So Bernoulli's defence of this laſt opinion is without force.

When we have made uſe of theſe arguments with ſome zealous partizans of Mr Leibnitz's doctrine, they have anſwered, that if indeed this independence of the relative motions of terreſtrial bodies were obſerved to obtain exactly, it would be a concluſive argument. But the motion with which all is carried along is ſo great in compariſon with the motions which we can produce in our experiments, that the ſmall additions or diminutions that we can make to the velocity of this common motion muſt obſerve very nearly the proportions of the additions or diminutions of their ſquares. The differences of the ſquares of 2, 3, and 4, are very unequal; but the differences of the ſquares of 9, 10, 11, are much nearer to the ratio of equality; and the differences of the ſquares of 1000001, 1000002, 1000003, do not ſenſibly deviate from this ratio. But it is not fact that we cannot produce motions which have a very ſenſible proportion to the common motion. The motion of a cannon ball, diſcharged with one-third of its weight of powder, is nearly equal to that of the rotation of the earth's equator. When, therefore, we diſcharge the ball eaſtward, we double its motion; when to the weſtward, we deſtroy it. Therefore, according to Leibnitz, the action in the firſt caſe is three times the action in the ſecond. In the firſt caſe it changes the ſquare of the velocity (which we may call 1) from 1 to 4; and, in the ſecond, it changes it from 1 to 0. But ſay the Leibnitzians, the velocity of rotation is but $\frac{1}{63}$ of the orbital velocity of the earth, and our obſervations of the velocities of cannon bullets are not ſufficiently exact to enſure us againſt an error of $\frac{1}{31\frac{1}{2}}$. But the later obſervations on the peculiar motions of the fixed ſtars concur in ſhewing, that the ſun, with his attending planets, are carried along with a very great motion, which, in all probability, has a ſenſible ratio to the orbital motion of the earth. This muſt make a prodigious change on the earth's abſolute motion, according as her orbital motion conſpires with, oppoſes, or croſſes, this other motion: the earth may even be at abſolute reſt in ſome points of its orbit. Thus will the compoſition with the motions produced in our experiments be ſo varied, that caſes muſt occur when the difference of the reſults of the two meaſures of force will be very ſenſible.

But, farther, they have not attended to the agreement of our experiments, when the diſcharges of cannon are made in a direction tranſverſe to that of the common motion. Here the immenſity of the common motion, and the minuteneſs of our experimental velocities, can have no effect in diminiſhing the difference of the reſults of the two doctrines. This will appear diſtinctly to every reader who is much converſant in diſquiſitions of this kind: and it is in theſe more moderate motions that the complete independence of the relative motions on the common motions moſt accurately appears. Pendulum clocks and watches have been often executed which do not deviate from perfect equability of motion one part in 86400. This could not be obtained in all directions of the oſcillations, if the forces deviated from the ratio of the velocities one part in 86400.

Perfect agreement of the abſtract notion of force with all our accurate obſervations of the exertions of natural powers,

On the whole, we may conſider it as eſtabliſhed on the ſureſt foundation, that the action of thoſe powers of natural bodies which we call *preſſures*, ſuch as the force of ſprings, the exertions of animals, the coheſion of bodies, as well as the action of thoſe other incitements to motion which we call *attractions* and *repulſions*, ſuch as gravitation, magnetiſm and electricity—is proportional to the change of velocity produced by it. And we muſt obſerve here, that this is not a mere mode of conception, the reſult of the laws of human thought, which cannot conceive a natural power as the cauſe of motion otherwiſe than by its producing motion, and which cannot conceive any degree of *moving* power different from the degree of the motion. This is the abſtract doctrine, and is true whether the preſſures are proportional to the velocities, or to the ſquares of the velocities. But we ſee farther, that whatever is the preſſure of a ſpring (for example) on a quieſcent body, yet the preſſure actually exerted in producing a double velocity is only double and not quadruple as our firſt imperfect obſervations make us imagine.

79
Newton's third law of motion is founded on experience alone, and is not a neceſſary truth.

Sir Iſaac Newton has added another propoſition to the number of laws of motion, namely, that *every action is accompanied by an equal and contrary reaction.* But in affirming this to be a law of nature, he only means that it is an univerſal fact; and he makes this affirmation on the authority of what he conceives to be a law of human thought; namely, that thoſe qualities which we find in all bodies on which we can make experiments and obſervations are to be conſidered as univerſal qualities of body. But we have limited the term *law of motion* to thoſe conſequences that neceſſarily flow from our notions of motion, of the cauſes of its production and changes. Now this third Newtonian propoſition is not ſuch a reſult. A magnet is ſaid to act on a piece of iron when, and only when, the vicinity of the magnet is obſerved to be accompanied by certain motions of the iron. But it by no means follows from this obſervation, that the preſence of the iron ſhall be accompanied by any motion, or any change of ſtate whatever of the magnet, or any appearance that can ſuggeſt the notion that the iron acts on the magnet. When this was obſerved, it was accounted a diſcovery. Newton *diſcovered*, that the ſun acts on the planets, and that the earth acts on the moon; and Kepler *diſcovered*, that the moon reacts on the earth. Newton had obſerved, that the iron reacts on the magnet; that the actions of electrified bodies were mutual; and that every action of ſublunary bodies was, in fact, accompanied by an equal and contrary reaction. On the authority of his rule of philoſophizing he affirmed, that the planets react on the ſun, and that the ſun is not at reſt, but is continually agitated by a ſmall motion round the general centre of gravitation. He pointed out ſeveral conſequences of this reaction. Aſtronomers examined the celeſtial motions more narrowly, and found that thoſe conſequences do really obtain, and diſturb all the planetary motions. It is now found that this reciprocity of action obtains throughout the ſolar ſyſtem with the utmoſt preciſion, and that the third Newtonian propoſition is really a law of nature, although it is not a law of human thought. It is a diſcovery. The contrary involves no abſurdity or contradiction. It would indeed be contrary to experience; but things might have been otherwiſe. It is conceivable, and poſſible, that a ball A ſhall ſtrike another equal ball B, and carry it along with it, without any diminution of its velocity. The fact, that the velocity of A is reduced to one-half, is the indication of a force reſiding in B, which force changes the motion of A; and the intenſity of this force is learned from the change which it produces. This *is found* to be equal to the change produced by A on B. And thus the reaction of B is *diſcovered* to be equal to the action of A.

It is highly probable, that this univerſality and equality of reaction to action is the conſequence of ſome general principle, which we may in time diſcover; meanwhile we are intitled to ſuppoſe it univerſal, and to reaſon from this topic in our diſquiſitions about the actions of bodies on each other.

Maupertuis, Leibnitz, and other philoſophers, have entertained very inadequate opinions concerning the foundation of the laws of motion.

Although the celebrated philoſophers of Europe have at laſt agreed in the reception of the two propoſitions ſo largely diſcuſſed by us as the laws of motion, they have differed exceedingly in their opinion about their origin and validity: Some aſſerted that they are entirely matters of experience; while others affirmed them to be neceſſary truths. The royal academy of Berlin the hand, or ſliding down an uniform ſlope, has its motion continually accelerated, and that the motion of an arrow riſing perpendicularly through the air is continually retarded; and they feel no difficulty in conceiving theſe changes of motion as the effects of the continual operation of their weight or heavineſs. The falling ſtone is in a different condition in reſpect of motion in the beginning and the end of its fall. In what reſpect do theſe ſtates of the body differ? Only in reſpect to what we call its *velocity*. This is an affection of motion; it is an expreſſion of the relation between the two notions or ideas which concur to form the idea of motion, namely, the ſpace and the time. Theſe are all the circumſtances that we obſerve in a motion. Time elapſes, and during its currency a ſpace is deſcribed. The term *velocity* expreſſes the magnitude of the ſpace which correſponds to ſome unit of time. Thus, the rate of a ſhip's motion is determined, when we ſay that it is nine miles in an hour, or nine miles per hour. We ſometimes ſay (but aukwardly) "The motion is at the rate, or with the velocity, of a mile in three days." It is moſt conveniently expreſſed by a number of ſome given units of length, which completely make up the line deſcribed during this unit of time. But the mechanicians expreſs it in a way more general by a fraction, of which the numerator is a number of inches, feet, yards, fathoms, or miles, and the denominator is the number of ſeconds, minutes, or hours, employed in moving along this line. This is a very proper expreſſion; for when we ſpeak of any velocity, and continue to reaſon from it, we conceive ourſelves to ſpeak of ſomething that remains the ſame, in the different occaſions of uſing the term. Now if the velocity be conſtant, it is indifferent how long the line may be; becauſe the time of its deſcription will be lengthened in the ſame proportion. Thus if 48 feet be deſcribed in 12 ſeconds, 36 feet will be deſcribed in 9 ſeconds, 16 feet will be deſcribed in 4 ſeconds, &c. Now $\frac{48}{12}$, $\frac{36}{9}$, and $\frac{16}{4}$, are fractions of equal value, being equal to $\frac{4}{1}$, or 4, that is, to the velocity of 4 feet per ſecond. The value of this fraction, or the quotient of the number of the units of length, divided by the number of units of time, is the number of thoſe units of length deſcribed uniformly in one unit of time.

71 Circumſtantial expoſition of our conception of the condition of a body in reſpect to motion.

Magnitude of a velocity of which we have no actual meaſure.

But how ſhall we determine the velocity in any inſtant or in any point of a motion that is continually changing? Suppoſe that a body has fallen 144 feet, and that we would aſcertain its velocity in that point of its fall, or the velocity which it has in paſſing through that point? In the next ſecond the body falls 112 feet farther. This cannot be the meaſure of the velocity at the beginning of the fourth or the end of the third ſecond. It is two great. The fall during the preceding ſecond was 80 feet. This is too ſmall. The mean of theſe two, or $\frac{80+112}{2}$, $=\frac{192}{2}$, $=96$, is probably more exact. Due attention to the nature of this motion ſhews us, that 96 is the proper meaſure, or that the motion at that inſtant is at the rate of 96 feet per ſecond. But it is peculiar to this kind of motion that the half ſum of the ſpaces deſcribed in two ſucceeding equal moments is the meaſure of the velocity in the middle inſtant. Therefore this method will not generally give an accurate meaſure. Yet it is indiſpenſably neceſſary to obtain ſome accurate meaſure; for it is in this particular alone that the ſtate of the body differs from its ſimilar ſtate in another inſtant. The difference of place makes no diſtinction; for if a body continue its motion unchanged, its condition in every different inſtant of time, or point of ſpace, is unchanged or the ſame. The change of place is not a change of motion, but is involved in the very conception of the continuation of the motion. The change of condition conſiſts, therefore, in the change of velocity: Therefore the change of velocity is the only indication, and the only meaſure of the action (perhaps accumulated) of the changing force. It is therefore the chief object of our ſearch; and accurate meaſures of velocity are abſolutely neceſſary.

When the velocity changes continually, there can be no *actual* meaſure of it. In what then does the magnitude of a velocity conſiſt, when there is no actual meaſure of it? It is a certain undeſcribable DETERMINATION; by which, if not changed, a certain ſpace *would* be uniformly deſcribed in a given unit of time. Thus we know, that if, when a ſtone has fallen 16 feet, its motion be directed along a horizontal plane, without diminution, it will move on for ever at the rate of 32 feet per ſecond. The ſpace which would be thus deſcribed is not the velocity, but the meaſure of the velocity. But the proportions of thoſe ſpaces, being the proportions of thoſe meaſures, are the proportions of the velocities themſelves. We may diſcover theſe proportions in the following manner:

72 Momentary proportion of velocities that are continually changing.

Let ACG (fig. 13.) be a line deſcribed by a body with a motion anyhow continually, but gradually, varied; and let it be required to determine the proportion of the velocity in any point C to the velocity in any other point F.

Fundamental requiſite in all mechanical diſquiſitions.

AXIOM.—If A be to B in a ratio that is greater than any ratio leſs than that of C to D, but leſs than any ratio greater than that of C to D, then A is to B as C to D. Take the ſtraight line *a c g* to repreſent the time of the body's motion along ACG, ſo that the points *a*, *c*, *f*, *g*, may repreſent the inſtants of time in which the body paſſes through the points A, C, F, G; and the portions *a c*, *c f*, *f g*, of the line *a g*, may repreſent the times employed in deſcribing the portions AC, CF, FG; and therefore *a c* is to *a f* as the time of deſcribing AC to the time of deſcribing AF.

Moreover, let *h k n o* be a line ſo related to the ſtraight line *a c f g*, by the perpendicular ordinates *a h*, *c k*, *f n*, *g o*, that the areas *a c k h*, *a f n h*, *a g o h*, may be proportional to the portions AC, AF, AG, of the line deſcribed by the moving body; and let this relation be true with reſpect to every point B, D, E, &c. and the correſponding points *b*, *d*, *e*, &c.

Then it is affirmed, that *the velocity in the point* C *is to the velocity in the point* F *as c k is to f n*.

Let the equal lines *b c*, *c d*, *e f*, *f g*, repreſent equal moments of time, and let B, D, E, G, be the points through which the body is paſſing at the inſtants *b*, *d*, *e*, *g*. Then the areas *b i k c*, *c k l d*, *e m n f*, *f n o g*, will repreſent, and be proportional to, the ſpaces BC, CD, EF, FG, which are deſcribed during the moments *b c*, *c d*, *e f*, *f g*.

Draw *t p* parallel to *a g*, ſo as to make the rectangle *b t p c* equal to the trapezium *b i k c*; and draw the lines *q v*, *u r*, *s x*, in the ſame manner, ſo that each rectangle may be equal to its correſponding trapezium.

If the motions had been uniform during the moments bc and fg, that is, if the ſpaces BC and FG had been uniformly deſcribed, then the velocity in the point C would have been to the velocity in the point F as cp to fs: For ſince the rectangles $btpc$ and $fsxg$ are reſpectively equal to the trapeziums $bikc$ and $fnog$; and ſince $bikc$ is to $fnog$ as BC is to FG, the rectangle $btpc$ is to the rectangle $fsxg$ as BC to FG. But becauſe theſe two rectangles have equal altitudes bc and fg, they are to each other in the proportion of their baſes cp and gx, or cp and fs. Therefore BC is to FG as cp to fs. But if BC and FG are uniformly deſcribed in equal times, they are proportional to the velocities of thoſe uniform motions. Therefore cp is to fs as the velocity with which BC is uniformly deſcribed to the velocity with which FG is uniformly deſcribed in an equal time.

But the motion expreſſed by the figure is not uniform, becauſe the line hlo recedes from the axis ag, and the areas, cut off by the parallel ordinates, increaſe in a greater proportion than the correſponding parts of the axis; that is, the ſpaces increaſe faſter than the times, for the moments bc, cd, ef, fg, being all equal, it is evident that the correſponding ſlips of the area continually augment. The motion is ſwifter at the inſtant c than at the inſtant b, and the velocity at the inſtant c is *greater* than that with which the ſpace BC would be uniformly deſcribed in the ſame time. For the ſame reaſon, the velocity at the inſtant f is *leſs* than that with which the ſpace FG would be uniformly deſcribed in the ſame time. Therefore the velocity at the inſtant c is to the velocity at the inſtant f in a greater ratio than that of cp to fs. In the very ſame manner, it will appear, by comparing the motion during the moment cd with the motion during the moment ef, that the velocity at the inſtant c is to the velocity at the inſtant f in a leſs ratio than that of cq to fr.

Therefore the velocity in the point C is to the velocity in the point F in a greater ratio than that of cp to fs, but in a leſs ratio than that of cq to fr.

But by continually diminiſhing the equal moments bc, cd, ef, fg, it is evident that cp and cq continually approach to equality with ck; and fr and fs continually approach to equality with fn, that when cp is leſs than ck, fs is greater than fn, and when cq is greater than ch, fr is leſs than fn.

Therefore the velocity in the point C is to the velocity in the point F in a ratio that is greater than the ratio of *any* line leſs than ck to *any* line greater than fn, but which is leſs than the ratio of any line greater than ck to any line leſs than fn. Therefore the ratio of the velocity in C to the velocity in F is greater than any ratio that is leſs than that of ck to fn; but it is leſs than any ratio that is greater than that of ck to fn. Therefore the velocity in the point C is to the velocity in the point F as ck to fn.

This important theorem may be expreſſed in more general terms as follows:

If the abſciſſa ag *of a line* hko *repreſent the time of any motion, and if the areas bounded by parallel ordinates be proportional to the ſpaces deſcribed, the ordinates are proportional to the velocities.*

REMARK. The propriety or aptitude of expreſſing the time by the portions of the axis acg, will, perhaps, appear more clearly in the following manner.

Let acg be any ſtraight line, and let hkv be another line, ſtraight or curved. Let the ſtraight line ahz, perpendicular to ag, be carried uniformly down along this line, keeping always perpendicular to it, and therefore always parallel to its firſt poſition ahz. In its various ſituations ckz, emz, &c. it will cut off areas $ackh$, $aemh$, &c. bounded by the axis by the ordinates ah and ck, or by the ordinates ah and em, &c. and by the line hkg. By this motion the moveable ordinate is ſaid, in a language of modern geometry, to *generate* the areas $ackh$, $aemh$, &c. At the ſame time, let a point A move along the line ACG, ſetting out from A at the inſtant when the line az ſets out from a; and let the motion of the point A be ſo regulated, that the ſpaces AB, AC, AD, &c. generated by this motion, may increaſe at the ſame rate with the areas ab, ih, $ackh$, $adlh$, &c. or ſuch that we ſhall have AB to AC as $abih$ to $ackh$, &c. It is plain, that the motion along AG is the ſame with that deſcribed in the enunciation of the propoſition: for becauſe the motion of the ordinate az, along the axis ag, is ſuppoſed to be uniform, the ſpaces ab, ac, ad, &c. are proportional to the times in which they are deſcribed, and may therefore be taken to meaſure or to repreſent thoſe times.

73 Cor. 1. *In a motion continually varied, the velocities in the different points of the path are to each other in the limiting or ultimate ratio of the ſpaces deſcribed in equal times,* thoſe times being ſuppoſed to diminiſh continually: for it is evident, that if the equal moments bc, cd, ef, fg, are ſuppoſed to diminiſh continually, till the inſtants b and d coaleſce with c, and the inſtants e and g coaleſce with f; then the ratio of ck to fn is the limit of the continually increaſing ratio of cp to fs, or of the continually diminiſhing ratio of cq to fr. Sir Iſaac Newton calls this the ultimate ratio of cp to fs, or of cq to fr. Now the ratio of cp to fs is, by conſtruction, the ſame with the ratio of the rectangle $btpc$ to the rectangle $fsxg$, and the ratio of cq to fr is the ſame with the ratio of the rectangle $cqvd$ to the rectangle $eurf$. But the ratio of the rectangle $btpc$ to the rectangle $fsxg$ is the ſame with the ratio of the ſpace $bikc$ to the ſpace $fnog$; that is (by hypotheſis), the ſame with the ratio of the ſpace BC to the ſpace FG; and the ratio of the rectangles $cqvd$ and $eurf$ is the ſame with that of the ſpaces CD and EF. Therefore the ratio of the velocity at C to the velocity at F is the ſame with the ultimate ratio of the ſmall increments BC, FG, or CD, EF of the ſpaces generated in very ſmall and equal times.

It is alſo evident, that becauſe the ratio of ck to fn is the limit both of the ratio of cp to fs and of the ratio of cq to fr, theſe ultimate ratios are the ſame, and that we may ſay that the velocity in C is to the velocity in F in the ultimate ratio of BC to EF, or in the ultimate ratio of CD to FG.

We alſo can eaſily perceive, that the ratio of the area $bikc$ to the area $emnf$ approaches more near to the ratio of ck to fn as we take the moments bc and ef ſmaller. Therefore, in many caſes of practice, where it may be eaſy to meaſure the ſpaces deſcribed in the different ſmall moments of the motion, but difficult to aſcertain their ultimate ratio, ſo as to obtain accurate meaſures of the proportions of the velocities, we may reduce the errors of meaſurement to ſomething very inſignificant, by taking theſe moments extremely ſmall;

f Accele- ted and etarded otions.

and we make the ſame affirmation concerning the magnitudes repreſented by theſe lines. We ſay that the velocity at the inſtant *b* is to the velocity at the inſtant *d* as the time *a b* is to the time *a d*. We ſay, in terms ſtill more general, that the velocities are proportional to the times from the beginning of the motion. We moreover perceive, that the ſpaces are alſo proportional to the ſquares of the acquired velocities; or the velocities are as the ſquare roots of the ſpaces.

We can farther infer, from the properties of the triangle, that the momentary increments of the ſpaces are proportional to the momentary increments of the ſquares of the times, or of the ſquares of the velocities.

We alſo obſerve, that not only the whole acquired velocities are proportional to the whole elapſed times, but that the increments of the velocities are proportional to the times in which they are acquired; for $\pi\ \varkappa$ is to $\rho\ \varphi$ as *b c* to *d f*, &c. Equal increments of velocity are therefore acquired in equal times. Therefore ſuch a motion may, in great propriety of language, be denominated a UNIFORMLY ACCELERATED MOTION; that is, *a motion in which we obſerve the ſpaces proportioned to the ſquares of the times, is a motion uniformly accelerated;* and ſpaces in the duplicate ratio of the times form the oſtenſible characteriſtic of an uniformly accelerated motion.

79 Laſtly, if we draw $\varepsilon\ \lambda$ parallel to the axis *a b*, we perceive that the rectangle $a\ e\ \varepsilon\ \lambda$ is double of the triangle $a\ e\ \varepsilon$. Now becauſe *a e* repreſents the time of the motion, and $e\ \varepsilon$ repreſents the acquired velocity, the rectangle $a\ e\ \varepsilon\ \lambda$ will repreſent the ſpace which would be uniformly deſcribed with the velocity $e\ \varepsilon$ during the time *a e*. But the triangle $a\ e\ \varepsilon$ repreſents the ſpace really deſcribed with the uniformly accelerated motion during the ſame time. Hence we infer, that the ſpace that is deſcribed in any time, with a motion increaſing uniformly from nothing, is one half of the ſpace which would be uniformly deſcribed during the ſame time with the final velocity.

Theſe are but a part of the inferences which we may draw from the geometrical properties of thoſe repreſentations which we had ſelected of the different meaſureable affections of motion. We may affirm, with reſpect to the motions themſelves, all the inferences which relate to magnitude and proportion, and thus improve our knowledge of the motions.

We took the opportunity of this very ſimple and perſpicuous example, to give our young readers a juſt conception of the *mathematical method* of proſecuting mechanical knowledge, and to make them ſenſible of the unqueſtionable authority for every theorem deduced in this manner.

One of the moſt important is, to diſcover the accumulated reſult of a motion of which we only obſerve the momentary increments. This is to be done by finding the area, or portions of the area, of the mixtilineal ſpace *a g o h;* and it is evidently analogous to the inverſe method of fluxions, or the integral calculus.

In moſt caſes, we muſt avail ourſelves of the corollary $\dot{s} \doteqdot v\ \dot{t}$, and we obtain the ſolution of our queſtion only in the caſes where our knowledge of the quantities $\dot{s}$, $\dot{t}$ and v (conſidered as geometrical magnitudes, that is, as lines and ſurfaces), enables us to diſcover *s* and *t*.

OF ACCELERATING AND RETARDING FORCES.

Of Accelerating and Retarding Forces. 80

HAVING thus diſcovered the proportions of the velocities in motions varying in any manner whatever, we can obſerve the variations which happen in them. Theſe variations are the effects, and the only marks and meaſures of the changing forces. They are the characteriſtics of their kinds (conſidered merely as moving forces); that is, the indications of the directions in which they act; for this is the only difference *in kind* of which they are ſuſceptible in this general point of view. If they increaſe the velocity, their direction muſt be conceived as the ſame with that of the previous motion; becauſe the reſult of the action of a force is equivalent to the compoſition of the motion which that force would produce in a quieſcent body with the motion already exiſting; and an increaſe of velocity is equivalent to the compoſition of a motion in the ſame direction.

Having no other mark of the force but the acceleration, we have no other name for it in the abſtract doctrines of dynamics, and we call it an ACCELERATING FORCE. Had it retarded the motion, we ſhould have called it a RETARDING FORCE.

In like manner, we have no meaſure of the *magnitude* or *intenſity* of an accelerating force, but the acceleration which it produces. In order therefore to inveſtigate the powers which produce all the changes of motion, we muſt endeavour to obtain meaſures of the acceleration.

A continual increaſe of velocity is the effect of the continued action of accelerating forces. If equal increments of velocity are produced in every ſucceeding equal moment of time, we cannot conceive that there is any change in the accelerating force. Therefore a uniformly accelerated motion is the mark of the unvaried action of an accelerating force, that is, of the continued action of a conſtant force; of a force whoſe intenſity is always the ſame. When therefore we obſerve a body deſcribe ſpaces proportional to the ſquares of the times, we muſt infer that it is urged forward by a force whoſe intenſity does not change; and, on the other hand, a conſtant force muſt produce a uniformly accelerated motion by its continued action. And if any previous circumſtances aſſure us of this continued action of an invaried force, we may make all the inferences which were mentioned under the article of uniformly accelerated motion.

81 Meaſure of an accelerating force.

That force muſt ſurely be accounted double which produces a double increment of velocity in the ſame time by its uniform action, we can form no other eſtimation of its magnitude. And, in general, *accelerating forces muſt be accounted proportional to the increments of velocity which they produce, by acting uniformly during the ſame or equal times.*

Suppoſing them to act on a body at reſt. Then the velocity produced is itſelf the increment; and we muſt ſay, that accelerating forces are proportional to the velocities which they generate in a body in equal times. And becauſe we found (n° 79.), that the ſpace deſcribed with a uniformly accelerated motion is half the ſpace which would be uniformly deſcribed in the ſame time with the final velocity, which ſpace is the direct meaſure of this velocity, and becauſe halves have the ſame proportion with the wholes—we may ſay, that *accelerating*

accelerating forces are proportional to the ſpaces through which they impel a body from reſt in equal times by their uniform action.

Another meaſure.

This is an important remark; becauſe it gives us an eaſy meaſure of the force, without the trouble of firſt computing the velocities. It alſo gives us the only diſtinct notion that we have of the meaſurement of forces by the motions which they produce. When ſpeaking of the compoſition of forces, we diſtinguiſhed or denominated them by the ſides and diagonal of a parallelogram. Theſe lines muſt be conceived as proportional to the ſpaces through which the forces urge the body *uniformly* during the ſmall and inſenſible time of their action, which time is ſuppoſed to be the ſame for both forces; for the ſides of the parallelogram are ſuppoſed to be ſeparately deſcribed in equal times, and therefore to be proportional to the velocities generated by the conſtituent forces. If indeed the forces do not act uniformly, nor ſimilarly, nor during equal times, we cannot ſay (without farther inveſtigation) what is the proportion of the intenſity of the forces, nor can we infer the compoſition of their action. We muſt at leaſt ſuppoſe, that in every inſtant of this very ſmall time of their joint action, their direction remains unchanged, and that their intenſities are in the ſame ratio. We ſhall ſee by and bye, that with theſe conditions the ſides of the parallelogram are ſtill proportional to the velocities generated. In the mean time, we may take the ſpaces through which a body is uniformly impelled from reſt (that is, with a uniformly accelerated motion) as the meaſures of the forces; yet theſe ſpaces are but the halves of the meaſures of the velocities. Then, if a body be moving with the velocity of 32 feet per ſecond, and an accelerating force acts on it during a ſecond, and if this force be ſuch that it would impel the body (from a ſtate of reſt) 16 feet, it will add to the body a velocity of 32 feet per ſecond. Accordingly, this is the effect of gravity—the weight of a pound of lead may be conſidered as a force which does not vary in its intenſity. We know that it will cauſe the lead to fall 16 feet in a ſecond; but if the body has already fallen 16 feet, we know that it is then moving with the velocity of 32 feet per ſecond. And the fact is, that it will fall 48 feet farther in the next ſecond, and will have acquired the velocity of 64 feet per ſecond. It has therefore received an augmentation of 32 feet of velocity by the action of gravity during the ſecond ſecond; and gravity is in fact a conſtant force, cauſing equal increments of velocity in equal times, however great the velocities may be. It does not act like a ſtream of fluid, whoſe impulſe or action diminiſhes as the ſolid body withdraws from it by yielding.

But ſuppoſing that we have not compared the increments of velocity uniformly acquired during equal times, in what manner ſhall we meaſure the accelerating forces? In ſuch a caſe, that force muſt be accounted double which generates the ſame velocity, by acting uniformly during half the time; for when the force is ſuppoſed invariable, the changes of velocity which it produces are proportional to the times of its action; therefore if it produces an equal velocity in half the time, it will produce a double velocity in an equal time, and is therefore a double force. The ſame may be ſaid of every proportion of time in which an equal change of velocity is produced by the uniform action of an accelerating force. The force muſt be accounted greater in the ſame proportion that the time required for the production of a given velocity in a body is leſs. Hence we infer, that *accelerating forces are inverſely proportional to the times in which a given change of velocity is produced by their uniform action.*

By combining theſe two propoſitions we eſtabliſh this general theorem;

82
Meaſur accelera ing for

Accelerating forces are proportional to the changes of velocity which they produce in a body by their uniform action directly, and to the times in which theſe changes are produced inverſely.

If, therefore, A and a are the forces, V′ and v' the changes of velocity, and T′ and t' the portions of time in which they are uniformly produced, we have

$$A : a = V't' : v'T', = \frac{V'}{T'} : \frac{v'}{t'}$$

$$\text{And } a \doteqdot \frac{v'}{t'}.$$

The formula $a \doteqdot \frac{v'}{t'}$ is not reſtricted to any particular magnitude of v' and t'. It is true, therefore, when the portion of time is diminiſhed without end; for ſince the action is ſuppoſed uniform, the increment of velocity is leſſened in the ſame proportion, and the value of the fraction $\frac{v'}{t'}$ remains the ſame. The characters or ſymbols v' and t' are commonly uſed to expreſs *finite* portions of v and t. The ſymbols $\dot{v}$ and $\dot{t}$ are uſed by Newton to expreſs the ſame things taken in the ultimate or limiting ratio. They are uſually conſidered as *indefinitely ſmall* portions of v and t. We ſhall abide by the formula $a \doteqdot \frac{\dot{v}}{\dot{t}}$.

83
Is an ab ſtract nu ber.

It muſt always be kept in mind, that v and t are abſtract numbers; and that v refers to ſome unit of ſpace, ſuch as a foot, an inch, a yard; and that t refers to ſome unit of time, ſuch as an hour, a minute, a ſecond; and eſpecially that a is the number of the ſame units of ſpace, which will be uniformly deſcribed in *one* unit of the time with the velocity generated, by the force acting uniformly during *that* unit. It is twice the ſpace actually deſcribed by the body during that unit when impelled from reſt by the accelerating force. It is neceſſary to keep hold of theſe clear ideas of the quantities expreſſed by the ſymbols.

Meaſure a change velocity.

On the other hand, when the meaſure of the accelerating force is previouſly known, we employ the theorem $a\,t' = v'$; that is, the addition made to the velocity during the whole, or any part, of the time of the action of the force is obtained by multiplying the acceleration of one unit of time by the number of ſuch units contained in t'.

Theſe m ſures ex preſs th greateſt part of knowled of mech nical na ture.

Theſe are evidently leading theorems in dynamics; becaſe all the mechanical powers of nature come under the predicament of accelerating or retarding forces. It is the collection of theſe in any ſubject, and the manner in which they accompany, or are inherent in it, which determine the mechanical character of that ſubject; and therefore the phenomena by which they are brought into view are the characteriſtic phenomena. Nay, it may even be queſtioned, whether the phenomena bring any thing more into view. This force, of which we ſpeak ſo familiarly, is no object of diſtinct contemplation; it is merely a ſomething that is proportional to $\frac{\dot{v}}{\dot{t}}$. And when we obſerve, that the $\frac{\dot{V}}{\dot{T}}$, found in the motions that reſult from the vicinity of a body A, is double of the $\frac{\dot{v}}{\dot{t}}$, which reſults from the vicinity of another body B; we ſay that a force reſides in A, and that it is double of the force reſiding in B. The accelerations are the things immediately and truly expreſſed by theſe ſymbols. And the whole ſcience of dynamics may be completely taught without once employing the word *force*, or the conception which we imagine that we form of it. It is of no uſe till we come to ſtudy the mechanical hiſtory of bodies. Then, indeed, we muſt have ſome way of expreſſing the fact, that an acceleration $= \frac{32 \text{ feet}}{1''}$ is obſerved in every thing on the ſurface of this globe; and that an acceleration $= \frac{418 \text{ feet}}{1''}$ is obſerved over all the ſurface of the ſun. Theſe facts are characteriſtic of this earth and of the ſun; and we expreſs them ſhortly by ſaying, that ſuch and ſuch forces reſide in the earth and in the ſun. It will preſerve us from many miſtakes and puzzling doubts, if we reſolutely adhere to this meaning of the term *force;* and this will carry mathematical evidence through the whole of our inveſtigations.

84 nother eaſure of celerat- g force.

As velocity is not an immediate object of contemplation, and all that we obſerve of motion is a ſpace and a time, it may be proper to give an expreſſion of this meaſure of accelerating force which involves no other idea. Suppoſing the body to have been previouſly at reſt, we have $a \doteqdot \frac{v}{t}$. Multiply both parts of the fraction by t, which does not change its value, and we have $a \doteqdot \frac{vt}{t^2}$. But $vt = s$; and therefore $a \doteqdot \frac{s}{t^2}$.

The formula $a = \frac{s}{t^2}$ is equivalent to the proportion $t^2 : 1 = s : a$; and a would then be the ſpace through which the accelerating force would impel the body in one unit of the time t. But this is only half of the meaſure of the velocity which the accelerating force generates during that unit of time. For this reaſon we did not expreſs the accelerating force by an ordinary equation, but uſed the ſymbol $\doteqdot$. In this caſe, therefore, of uniform action, we may expreſs the accelerating force by $a = \frac{2s}{t^2}$.

The following theorem is of ſtill more extenſive uſe in all dynamical diſquiſitions.

85 Moſt gene- al meaſure f accelera- ing force.

Accelerating forces are proportional to the momentary increments of the ſquares of the velocities directly, and as the ſpaces along which they are uniformly acquired inverſely.

Let A′B, A′C, and AD (fig. 14.), be three lines, deſcribed in the ſame or equal times by the uniform action of accelerating forces; the motions along theſe lines will be uniformly accelerated, and the lines themſelves will be proportional to the forces, and may be employed as their meaſures. On the greateſt of them AD, deſcribe the ſemicircle ABCD, and apply the other two lines A′B, A′C as chords AB, AC. Draw EB, FC perpendicular to AD. Take any ſmall portions Bb, Cc of AB and AC, and draw be, cf perpendicular to AD, and Eh and Fk parallel to AB and AC.

Then, becauſe the triangles DAB and BAE are ſimilar, we have $\text{AD} : \text{AE} = \text{AD}^2 : \text{AB}^2$. And becauſe AD is to AB as the velocity generated at D is to the velocity generated at B (the times being equal), we have AD to AE as the ſquare of the velocity at D to the ſquare of the velocity at B; which we may expreſs thus:

$$\text{AD} : \text{AE} = \text{V}^2, \text{D} : \text{V}^2, \text{B}.$$

For the ſame reaſons we have alſo

$$\text{AD} : \text{AF} = \text{V}^2, \text{D} : \text{V}^2, \text{C}. \quad \text{Therefore}$$
$$\text{AE} : \text{AF} = \text{V}^2, \text{B} : \text{V}^2, \text{C}.$$

But becauſe in any uniformly accelerated motion, the ſpaces are as the ſquares of the acquired velocities, we have alſo

$$\text{AE} : \text{A}e = \text{V}^2, \text{B} : \text{V}^2 b, \text{ and}$$
$$\text{AF} : \text{A}f = \text{V}^2, \text{C} : \text{V}^2 c.$$

Therefore Ee is to Ff as the increment of the ſquare of the velocity acquired in the motion along Bb to the increment of the ſquare of the velocity acquired along Cc.

But, by ſimilarity of the triangles ABD and Eeh, we have

$$\text{AB} : \text{AD} = \text{E}e : \text{E}h; \text{ and, in like manner,}$$
$$\text{AD} : \text{AC} = \text{F}k : \text{F}f. \quad \text{Therefore}$$
$$\text{AB} : \text{AC} = \text{E}e \times \text{F}k : \text{F}f \times \text{E}h.$$

Now AB and AC are proportional to the forces which accelerate the body along the lines A′B and A′C; Ee and Ff are proportional to the increments of the ſquares of the velocities acquired in the motions along the portions Bb and Cc; and Eh and Fk are equal to thoſe portions reſpectively. The ratio of AB to AC is compounded of the direct ratio of Ee to Ff; and the inverſe ratio of Eh to Fk. The propoſition is therefore demonſtrated.

The proportion may be expreſſed thus:

$\text{AB} : \text{AC} = \frac{\text{E}e}{\text{E}h} : \frac{\text{F}f}{\text{F}k}$, and may be expreſſed by the proportional equation $\text{AB} \doteqdot \frac{\text{E}e}{\text{E}h}$ or, ſymbolically, $a \doteqdot \frac{(v^2)}{\dot{s}}$.

$v\dot{v}$ is but one half of the increment of v^2.

Remark. Becauſe the motion along any of theſe three lines is uniformly accelerated, the relation between ſpaces, times, and velocities, may be repreſented by means of the triangle ABC (fig. 15.); where AB repreſents the time, BC the velocity, and ABC the ſpace. If BC be taken equal to AB, the triangle is half of the ſquare ABCF of the velocity BC; and the triangle ADE is half of the ſquare ADEG of the velocity DE. Let Dd and Bb be two moments of time, equal or unequal. Then D$de$E and B$bc$C are half the increments of the ſquares of the velocities DE and BC, acquired during the moments Dd and Bb. It was demonſtrated, that the ratio of the area D$de$E to the area B$bc$C is compounded of the ratio of DE to BC, and the ultimate ratio of Dd to Bb. But Dd and

90 Their meaſures in uch caſes ow obained?

Therefore, in order to obtain meaſures of the accelerating forces, or at leaſt of their proportions, let the abſciſſa *aeg* (fig. 13.) of the line *hko* again repreſent the time of a motion. But let the areas bounded by parallel ordinates now repreſent the velocities, that is, let the whole area increaſe during the time *ag* at the ſame rate with the velocities of the motion along the line AG. In this caſe the ordinates *bi*, *ck*, *dl*, &c. will be as the accelerations at the inſtants *b*, *c*, *d*, &c. or in the points B, C, D, &c.

Theorems f moſt exenſive uſe.

This is demonſtrated in the ſame way as the former propoſition (n° 72.). If the accelerating force be ſuppoſed conſtant during any two equal moments *bc* and *fg*, the rectangles *bcpt* and *fgxs* would expreſs the increments of velocity uniformly acquired in equal times, and their baſes *cp* and *fs* would have the ratio of the accelerations, or of the accelerating forces. But as the velocities expreſſed by the figure increaſe faſter than the times during every moment, the force at the inſtant *c* is to the force at the inſtant *f* in a greater ratio than that of *cp* to *fs*; but, for ſimilar reaſons, it is in a leſs ratio than that of *cq* to *fr*; and therefore (as in the other propoſition) the force at the inſtant *c* is to the force at the inſtant *f* as *ck* to *fn*.

91 *Cor.* Becauſe *cp* is to *fs* in the ratio compounded of the direct ratio of the rectangle *cptb* to the rectangle *fsxg*, and the inverſe ratio of the altitude *bc* to the altitude *fg*; and becauſe theſe rectangles are proportional to the increments of velocity, and the ultimate ratio of the altitudes is the ultimate ratio of the moments or increments of the time—we muſt ſay, that *the accelerating forces (that is, their intenſities or preſſures producing acceleration) are directly as the increments of velocity, and inverſely as the increments of the times:* Which propoſition may be expreſſed, in regard to two accelerations A and *a*, by this analogy:

$$\mathrm{A} : a = \frac{\dot{\mathrm{V}}}{\dot{\mathrm{T}}} : \frac{\dot{v}}{\dot{t}}.$$

Or by the proportional equation $a \doteqdot \frac{\dot{v}}{\dot{t}}$. Alſo $a\dot{t} \doteqdot \dot{v}$, and $\int a\dot{t} = v'$. And thus do theſe theorems extend even to the caſes where there cannot be obſerved an immediate meaſure, either of velocity or of acceleration; becauſe neither the ſpace nor the velocity increaſes uniformly.

: Barv's Lect. ometr. ſſim.

The theorem $a \doteqdot \frac{\dot{v}}{\dot{t}}$ is employed when we would diſcover the variation in the intenſity of ſome natural power. We obſerve the motion, and repreſent it by a figure analogous to fig. 13. where the abſciſſa repreſents the times, and the area is made to increaſe at the ſame rate with the ſpaces deſcribed. Then the ordinates will repreſent the velocities, or have the proportion of the velocities. Then we may draw a ſecond curve on the other ſide of the ſame abſciſſa, ſuch that the areas of this laſt curve ſhall be proportional to the ordinates of the firſt. The ordinates of this laſt curve are proportional to the accelerating forces.

92 On the other hand, when we know from other circumſtances that a force, varying according to ſome known law, acts on a body, we can determine its motion. The intenſity of the force in every inſtant being known, we can draw a line ſo related to another line repreſenting the time that the ordinates ſhall be proportional to the forces: The areas will be proportional to the velocities. We can draw another curve to the ſame abſciſs, ſuch that the ordinates of this ſhall be proportional to the areas of the other, that is, to the velocities of the motion. The areas of this ſecond curve will be proportional to the ſpaces deſcribed.

93 All theſe theorems relate to *changes* of velocity; by which means they indicate *immediately* the operation of natural powers.

We muſt now obſerve, that all that has been ſaid concerning the effects of accelerating forces continually varying, relates to *changes* of motion, independent of what the abſolute motions may be. The areas of the line whoſe ordinates repreſent the velocities do not neceſſarily repreſent the ſpaces deſcribed, but the change made on the ſpaces deſcribed in the ſame time; not the motions, but the changes of motion. If, indeed, the body be ſuppoſed to be at reſt when the forces begin to act, theſe areas repreſent the very ſpaces that are paſſed over, and the ordinates are the very velocities. In every caſe, however, the accelerations are the real increments of the velocities.

This circumſtance gives a great extenſion to our theorems, and enables us to aſcertain the diſturbances of any ſpecies of regular motion, apart from the motions themſelves, and thus avoid a complication which would frequently be inextricable in any other way. And this proceſs, which is merely mathematical, is perfectly conformable to mechanical principles. It is in fact an application of the doctrine of the compoſition of motion; a doctrine rigidly demonſtrated when we meaſure a mechanical force by the *change* of motion which it produces. Acceleration is the continual compoſition of a new motion with the motion already produced.

No finite change of velocity can be produced in an inſtant by any accelerating force.

We may learn from this inveſtigation of the value of an accelerating force, that no finite change of velocity is effected in an inſtant by the action of an accelerating force. When the fig. 13. is uſed for the ſcale of accelerations, and they are repreſented by the ordinates of the line *hko*, the increment of velocity is repreſented by an area, that is, by a ſlip of the whole area; which ſlip muſt have ſome altitude, or muſt occupy ſome portion of the abſciſſa which repreſents time. Some portion of time, however ſmall it may be, muſt elapſe before any meaſurable addition can be made to the velocity. The velocity muſt change *continually*. As no motion can be conceived as inſtantaneous, becauſe this would be to conceive, that in one inſtant the moving particle is in every point of its momentary path; ſo no velocity can change, by a finite quantity, in one inſtant; becauſe this would be to conceive, that in that inſtant the particle had all the intervening velocities. The inſtant of change is at once the laſt inſtant of the preceding velocity, and the firſt of the ſucceeding, and therefore muſt belong to both. This cannot be conceived, or is abſurd. As a body, in paſſing from one part of ſpace to another, muſt paſs in ſucceſſion through all the intermediate places; ſo, in paſſing from one velocity to another, it muſt in ſucceſſion have all the intermediate velocities. It muſt be *continually* accelerated; we muſt not ſay *gradually*, however ſmall the ſteps.

94 More convenient manner of conſidering the action of forces, and more frequently coming into view.

But to return from this digreſſion:

The moſt frequent caſes which come under examination do not ſhew us the relation between the forces and times, but the relation between the forces and ſpaces.

and Bb are reſpectively equal to εe and $\varkappa c$. Therefore D$de$E is to B$bc$C, in the ratio compounded of the ratio of DE to BC, and the ultimate ratio of εe to $\varkappa c$. If we repreſent DE and BC by V and v, then εe and $\varkappa c$ muſt be repreſented by V′ and V′, the increments of V and v; and then the compound ratio will be the ratio of VV′ to vv'; and if we take the ultimate ratio of the moments, and conſequently the ultimate ratio of the increments of the velocities, we have the ratio of $V\dot{V}$ to $v\dot{v}$. If, therefore, V^2 and v^2 repreſent the ſquares of the velocities, $V\dot{V}$ and $v\dot{v}$ will repreſent, not the increments of thoſe ſquares, but half the increments of them.

We may now repreſent this propoſition concerning accelerating forces by the proportional equation $a \doteqdot \frac{v\dot{v}}{\dot{s}}$; and we muſt conſider this as equivalent with $a = \frac{V^2-v^2}{2\,(S-s)}$; keeping always in mind, that a, V, and v, relate to the ſame units of time and ſpace, and that a is that number of units of the ſcale on which S and s are meaſured, which is run over in *one* unit of time.

Meaſure of gravity conſidered as an accelerating force.

This will be more clearly conceived by taking an example. Let us aſcertain the accelerative power of gravity, ſuppoſing it to act uniformly on a body. Let the ſpaces be meaſured in feet and the time in ſeconds. It is a matter of obſervation, that when a body has fallen 64 feet, it has acquired a velocity of 64 feet per ſecond: and that when it has fallen 144 feet, it has acquired the velocity of 96 feet per ſecond. We want to determine what velocity gravity communicated to it by acting on it during one ſecond. We have $V^2 = 9216$, and $v^2 = 4096$; and therefore $V'^2 - v^2 = 5120$. $S = 144$, and $s = 64$, and $S-s = 80$, and $2\,(S-s) = 160$. Now $a = \frac{5120}{160}, = 32$. Therefore gravity has generated the velocity 32 feet per ſecond by acting uniformly during one ſecond.

86 *The augmentation of the ſquare of the velocity is proportional to the force and to the ſpace jointly.* For, becauſe $a = \frac{v\dot{v}}{\dot{s}}$, we have $a\dot{s} = v\dot{v}$.

Thus we learn, that a given force, acting uniformly on a body along a given ſpace, produces the ſame increment of the ſquare of the velocity, whatever the previous velocity may have been. Alſo, in the ſame manner as we formerly found that the augmentation of the velocity was proportioned to the time during which the force has acted, ſo the augmentation of the ſquare of the velocity is proportional to the ſpace along which it has acted.

Theorems reſpecting retarding forces.

It is pretty plain, that all that we have ſaid of the uniform action of an *accelerating* force may be affirmed of a *retarding force*, taking a diminution or decrement of velocity in place of an increment. A uniformly retarded motion is that in which the decrements of velocity in equal times are equal, and the whole decrements are proportional to the whole times of action. Such a motion is the indication of a conſtant or invariable force acting in a direction oppoſite to that of the motion. We conceive this to be the caſe when an arrow is ſhot perpendicularly upwards; its weight is conceived as a force continually preſſing it perpendicularly downwards. In ſuch motions, however great the initial velocity may be, the body will come to reſt; becauſe a certain determined velocity will be taken from the body in each equal ſucceſſive moment, and ſome multiple of this will exceed the initial velocity. Therefore the velocity will be extinguiſhed before the end of a time that is the ſame multiple of the time in which the velocity was diminiſhed by the quantity above mentioned. It is no leſs evident, that the time in which any velocity will be extinguiſhed by an oppoſing or retarding force is equal to the time in which the ſame force would generate this velocity in the body previouſly at reſt. Therefore,

1. The times in which different initial velocities will be extinguiſhed by the ſame oppoſing force are proportional to the initial velocities. 87

2. The diſtances to which the body will go till the extinction of its velocity are as the ſquares of the initial velocities. 88

3. They are alſo as the ſquares of the times elapſed. 89

4. The diſtance to which a body, projected with any velocity, will go till its motion be extinguiſhed by the uniform action of a retarding force, is one half of the ſpace which it would deſcribe uniformly during the ſame time with the initial velocity.

Forces nerally riable i their in ſity.

It very rarely happens, that the force which accelerates the body acts uniformly, or with an unvaried intenſity. The attraction of a magnet, for example, increaſes as the iron approaches it. The preſſure of a ſpring diminiſhes as it unbends. The impulſe of a ſtream of water or wind diminiſhes as the impelled ſurface retires from it by yielding. Therefore the effects of accelerating forces are very imperfectly explained, till we have ſhewn what motions reſult from any given variation of force, and how to diſcover the variation of force from the obſerved motion. This laſt queſtion is perhaps the moſt important in the ſtudy of mechanical nature. It is only thus that we learn what is uſually called *the nature of a mechanical force.* This chiefly conſiſts in the relation ſubſiſting between the intenſity of the force and the diſtance of the ſubſtance in which it reſides. Thus the nature of that power which produces all the planetary motions, is conſidered as aſcertained when we have demonſtrated that its preſſure or intenſity is inverſely as the ſquare of the diſtance from the body in which it is ſuppoſed to reſide.

Acceleration expreſſes ſome relation of the velocity and time. This relation may be geometrically expreſſed in a variety of ways. In figure 13. the uniform acceleration or the unvaried relation between the velocity and the time is very aptly expreſſed by the conſtant ratio of the ordinates and abſciſſes of the triangle $ag\nu$. The ratio of $d\delta$ to ad is the ſame with that of $e\varepsilon$ to ae, or that of $f\varphi$ to af, &c.; or the ratio of the increment of velocity $\varpi\varkappa$ to the increment of the time $\beta\varpi$ or bc, or that of $i\varphi$ to εi, &c. This ratio $\varpi\varkappa : \beta\varpi$ is equivalent to the ſymbol $\frac{\dot{v}}{\dot{t}}$.

But when the ſpaces deſcribed in a varied motion are repreſented by the areas bounded by a curve line hko, we no longer have that conſtant ratio of the increments of the ordinates and abſciſſes.

Therefore, in order to obtain meaſures of the accelerating forces, or at leaſt of their proportions, let the abſciſſa *aeg* (fig. 13.) of the line *hko* again repreſent the time of a motion. But let the areas bounded by parallel ordinates now repreſent the velocities, that is, let the whole area increaſe during the time *ag* at the ſame rate with the velocities of the motion along the line AG. In this caſe the ordinates *bi*, *ck*, *dl*, &c. will be as the accelerations at the inſtants *b*, *c*, *d*, &c. or in the points B, C, D, &c.

90 Their meaſures in ſuch caſes how obtained? Theorems of moſt extenſive uſe.

This is demonſtrated in the ſame way as the former propoſition (n° 72.). If the accelerating force be ſuppoſed conſtant during any two equal moments *bc* and *fg*, the rectangles *bcpt* and *fgxs* would expreſs the increments of velocity uniformly acquired in equal times, and their baſes *cp* and *fs* would have the ratio of the accelerations, or of the accelerating forces. But as the velocities expreſſed by the figure increaſe faſter than the times during every moment, the force at the inſtant *c* is to the force at the inſtant *f* in a greater ratio than that of *cp* to *fs*; but, for ſimilar reaſons, it is in a leſs ratio than that of *cq* to *fr*; and therefore (as in the other propoſition) the force at the inſtant *c* is to the force at the inſtant *f* as *ck* to *fn*.

91 *Cor.* Becauſe *cp* is to *fs* in the ratio compounded of the direct ratio of the rectangle *cptb* to the rectangle *fsxg*, and the inverſe ratio of the altitude *bc* to the altitude *fg*; and becauſe theſe rectangles are proportional to the increments of velocity, and the ultimate ratio of the altitudes is the ultimate ratio of the moments or increments of the time—we muſt ſay, that *the accelerating forces (that is, their intenſities or preſſures producing acceleration) are directly as the increments of velocity, and inverſely as the increments of the times:* Which propoſition may be expreſſed, in regard to two accelerations A and *a*, by this analogy:

$$A : a = \frac{\dot{V}}{\dot{T}} : \frac{\dot{v}}{\dot{t}}.$$

Or by the proportional equation $a \doteq \frac{\dot{v}}{\dot{t}}$. Alſo $a\dot{t} \doteq \dot{v}$, and $\int a\dot{t} = v'$. And thus do theſe theorems extend even to the caſes where there cannot be obſerved an immediate meaſure, either of velocity or of acceleration; becauſe neither the ſpace nor the velocity increaſes uniformly.

See *Barrow's Lect. Geometr.* paſſim.

The theorem $a \doteq \frac{\dot{v}}{\dot{t}}$ is employed when we would diſcover the variation in the intenſity of ſome natural power. We obſerve the motion, and repreſent it by a figure analogous to fig. 13. where the abſciſſa repreſents the times, and the area is made to increaſe at the ſame rate with the ſpaces deſcribed. Then the ordinates will repreſent the velocities, or have the proportion of the velocities. Then we may draw a ſecond curve on the other ſide of the ſame abſciſſa, ſuch that the areas of this laſt curve ſhall be proportional to the ordinates of the firſt. The ordinates of this laſt curve are proportional to the accelerating forces.

92 On the other hand, when we know from other circumſtances that a force, varying according to ſome known law, acts on a body, we can determine its motion. The intenſity of the force in every inſtant being known, we can draw a line ſo related to another line repreſenting the time that the ordinates ſhall be proportional to the forces: The areas will be proportional to the velocities. We can draw another curve to the ſame abſciſs, ſuch that the ordinates of this ſhall be proportional to the areas of the other, that is, to the velocities of the motion. The areas of this ſecond curve will be proportional to the ſpaces deſcribed.

93 All theſe theorems relate to *changes* of velocity; by which means they indicate *immediately* the operation of natural powers.

We muſt now obſerve, that all that has been ſaid concerning the effects of accelerating forces continually varying, relates to *changes* of motion, independent of what the abſolute motions may be. The areas of the line whoſe ordinates repreſent the velocities do not neceſſarily repreſent the ſpaces deſcribed, but the change made on the ſpaces deſcribed in the ſame time; not the motions, but the changes of motion. If, indeed, the body be ſuppoſed to be at reſt when the forces begin to act, theſe areas repreſent the very ſpaces that are paſſed over, and the ordinates are the very velocities. In every caſe, however, the accelerations are the real increments of the velocities.

This circumſtance gives a great extenſion to our theorems, and enables us to aſcertain the diſturbances of any ſpecies of regular motion, apart from the motions themſelves, and thus avoid a complication which would frequently be inextricable in any other way. And this proceſs, which is merely mathematical, is perfectly conformable to mechanical principles. It is in fact an application of the doctrine of the compoſition of motion; a doctrine rigidly demonſtrated when we meaſure a mechanical force by the *change* of motion which it produces. Acceleration is the continual compoſition of a new motion with the motion already produced.

No finite change of velocity can be produced in an inſtant by any accelerating force.

We may learn from this inveſtigation of the value of an accelerating force, that no finite change of velocity is effected in an inſtant by the action of an accelerating force. When the fig. 13. is uſed for the ſcale of accelerations, and they are repreſented by the ordinates of the line *hko*, the increment of velocity is repreſented by an area, that is, by a ſlip of the whole area; which ſlip muſt have ſome altitude, or muſt occupy ſome portion of the abſciſſa which repreſents time. Some portion of time, however ſmall it may be, muſt elapſe before any meaſurable addition can be made to the velocity. The velocity muſt change *continually*. As no motion can be conceived as inſtantaneous, becauſe this would be to conceive, that in one inſtant the moving particle is in every point of its momentary path; ſo no velocity can change, by a finite quantity, in one inſtant; becauſe this would be to conceive, that in that inſtant the particle had all the intervening velocities. The inſtant of change is at once the laſt inſtant of the preceding velocity, and the firſt of the ſucceeding, and therefore muſt belong to both. This cannot be conceived, or is abſurd. As a body, in paſſing from one part of ſpace to another, muſt paſs in ſucceſſion through all the intermediate places; ſo, in paſſing from one velocity to another, it muſt in ſucceſſion have all the intermediate velocities. It muſt be *continually* accelerated; we muſt not ſay *gradually*, however ſmall the ſteps.

But to return from this digreſſion:

94 More convenient manner of conſidering the action of forces, and more frequently coming in to view.

The moſt frequent caſes which come under examination do not ſhew us the relation between the forces and times, but the relation between the forces and ſpaces.

Thus, when a piece of iron is in the neighbourhood of a magnet, or a planet is conſidered in the neighbourhood of the ſun, a force is acting on it in every point of its path, and we have diſcovered that the intenſity of this force varies in a certain proportion. Thus, a ſpring varies in its preſſure as it unbends; gunpowder preſſes leſs violently as it expands, &c. &c.

Our knowledge is generally confined to ſome ſuch effect as this. We know, that while a body is moving along a line ADE (fig. 16.), it is urged forward by a force, of which the intenſity varies in the proportion of the ordinates BF, CG, DH, EI, &c. of the line FGHI.

To inveſtigate the motion or change of motion produced by the action of this force, let CD be ſuppoſed a very ſmall portion of the ſpace s, which we may expreſs by s'. Draw GK perpendicular to DH. Then, if we ſuppoſe that the force acts with the unvaried intenſity CG through the whole ſpace CD, the rectangle CDKG will expreſs half of the increment of the ſquare of the velocity (n° 85.). We may ſuppoſe that the force acts uniformly along the adjoining ſmall ſpace Dr with the intenſity DH. The rectangle DHor will in like manner expreſs another half increment of the ſquare of the velocity. And in like manner we may obtain a ſucceſſion of ſuch increments. The aggregate or ſum of them all will be half the difference between the ſquare of the velocity at B and the ſquare of the velocity at E.

If we employ f to expreſs the indetermined or variable intenſity of the accelerating force, and v to expreſs the variable velocity, and v' its increment *uniformly* acquired; then the rectangle CDKG will be expreſſed by $f s'$. We have ſeen that this is equal to $v v'$. Therefore, in every caſe where we can tell the aggregate of all the quantities $f s$, it is plain that we will obtain half the difference between the ſquares of the velocities in B and E, on the ſuppoſition that the intenſity of the force was conſtant along each little ſpace, and varied by ſtarts. Then, by increaſing the number, and diminiſhing the magnitude, of thoſe little portions of the ſpace without end, it is evident that we terminate in the expreſſion of the real ſtate of the caſe, *i. e.* of a force varying continually; and that in this caſe the aggregate of theſe rectangles occupies the whole area AEIF, and is equivalent to the fluent of $f\dot{s}$, or to the ſymbol $\int f\dot{s}$, uſed by the foreign mathematicians to expreſs this fluent, which they indeed conceive as an aggregate of ſmall rectangles $f s'$. And we ſee that this area expreſſes half of the augmentation of the ſquare of the velocity. Therefore,

95 Moſt important theorem (*Newton's Principia*, I. 39.)

If the abſciſſa AE (fig. 16.) *of a line* FGI *is the path along which a body is urged by any accelerating force, and if the ordinates* BF, CG, DH, *&c. are proportional to the forces acting in the points* B, C, D, *&c. the intercepted areas* BCGF, BEIF, *&c. are proportional to the augmentations of the ſquare of the velocity.*

Obſerve that the areas BCGF and DEIH are alſo proportional to the augmentations made on the ſquares of the velocities in B and in D.

Obſerve alſo, that it is indifferent what may have been the original velocity. The action of the forces repreſented by the ordinates make always the ſame addition to its ſquare; and this addition is half the ſquare of the velocity which thoſe forces would generate in the body by impelling it from reſt in the point A.

96 Laſtly, on this head, obſerve, that we can ſtate what conſtant or variable force will make the ſame augmentation of the ſquare of the velocity by impelling the body uniformly along the ſame ſpace BE; or along what ſpace a given force muſt impel the body, in order to produce the ſame increaſe of the ſquare of its velocity. In the firſt caſe, we have only to make a rectangle BENφ, equal to the area BEIF, and then Bφ is the intenſity of the conſtant force wanted. In the ſecond caſe, in which the force EO is given, we muſt make the rectangle AαOE equal to the area BEIF, and AE is the ſpace required.

97 Converſe.

The converſe of this propoſition, *viz. If the areas are as the increments of the ſquare of the velocity, the ordinates are, as the forces*, is eaſily demonſtrated in the ſame way; for if the elementary areas CDKG and EIMe repreſent increments of the ſquares of the velocity, the accelerating forces are in the ratio compounded of the direct ratio of theſe rectangles and the inverſe ratio of their altitudes, becauſe theſe altitudes are the increments of the ſpace (n° 85). Now the baſe CG of the rectangle CDKG, is to the baſe EI of the rectangle EIMe in the ſame compounded ratio; therefore the force in C is to the force in E as CG to EI.

98 *Scales of* force, velocity, acceleration, time, &c.

The line $h\,k\,o$ (fig. 13.) was called by Dr Barrow (who firſt introduced this extenſive employment of motion into geometry), the SCALE *of velocities*; and the line FHL (fig. 16.) was named by him the *ſcale of accelerations*. Hermann, in his *Phoronomia*, calls it the *ſcale of forces*. We ſhall retain this name, and we may call $h\,k\,o$ of fig. 13. the *ſcale of* accelerations, when the areas repreſent the velocities. Sir Iſaac Newton added another ſcale of very great uſe, *viz.* a ſcale of times. It is conſtructed as follows.

99 Let ABE (fig. 16.) be the line along which a body is accelerated, and let FHI be the ſcale of forces, that is, having its ordinates FB, HD, IE, &c. proportional to the forces acting at B, D, E, F, &c.; let $f\,h\,i$ be another line ſo related to ABE, that Cg is to Ei in the inverſe ſubduplicate ratio of the area BFGC to the area BFIE; or, to expreſs it more generally, let the ſquares of the ordinates to the line $f\,g\,i$ be inverſely, as the arcas of the line FHI intercepted between theſe ordinates and the firſt ordinate drawn through B; then the times of the bodies moving from a ſtate of reſt in B are as the intercepted areas of the curve $f\,g\,i$.

For let CD and Ee be two very ſmall portions of the ſpace deſcribed in equal times. They will be ultimately as the velocities in C and E. The area FBCG is to the area FBEI as the ſquare of Ei to the ſquare of Cg (by conſtruction); but the area FBCG is to FBEI as the ſquare of the velocity at C to the ſquare of the velocity at E (by the propoſition); therefore the ſquare of the velocity at C is to the ſquare of the velocity at E as the ſquare of Ei to the ſquare of Cg; therefore Ei is to Cg as the velocity at C to the velocity at E, that is, as CD to Ee: but ſince $Ei : Cg = CD : Ee$, we have $Ei \times Ee = Cg \times CD$, and the elementary rectangles C$gk$D and Eime are equal, and may repreſent the equal moments of time in which CD and Ee were deſcribed. Thus the areas of the line $f\,g\,l$ will repreſent when the body is uniformly impelled along KC by the conſtant force IK, the ſquare of the velocity acquired at C is repreſented by half the rectangle IKCH, and therefore it is equal to the velocity which the variable force generates by impelling it along AC (by the way, an important obſervation). The body will deſcribe AC uniformly with this velocity in the ſame time that it is uniformly accelerated along KC. Therefore by *Cor.* 5. the propoſition is manifeſt.

Cor. 7. If two bodies deſcribe AC and KC by the action of forces which are every where propotional to the diſtances from C, their final velocities will be proportional to the diſtances run over, and the times will be equal.

For the ſquares of the final velocities are proportional to the triangles ADC, LKC, that is, to AC^2 KC^2, and therefore the velocities are as AC, KC. The times of deſcribing AC and KC uniformly, with velocities proportional to AC and KC, muſt be equal; and theſe times are in the ſame ratio (*viz.* that of radius to $\frac{1}{4}$ of the circumference) to the times of deſcribing AC and KC with the accelerated motion. Therefore, &c.

Thus by availing ourſelves of the properties of the circle, we have diſcovered all the properties or characters of a motion produced by a force always directed to a fixed point, and proportional to the diſtance from it. Some of theſe are remarkable, ſuch as the laſt corollary; and they are all important; for there are innumerable caſes where this law of action obtains in Nature. It is nearly the law of action of a bowſtring, and of all elaſtic bodies, when their change of figure during their mutual action is moderate; and it has been by the help of this propoſition, firſt demonſtrated in a particular caſe by Lord Brouncker and Mr Huyghens, that we have been able to obtain preciſe meaſures of time, and conſequently of actual motions, and conſequently of any of the mechanical powers of Nature. It is for this reaſon, as well as for the eaſy and perſpicuous employment of the mathematical method of proceeding that we have ſelected it.

Inſtead of giving any more particular caſes, we may obſerve in general, that if the intenſity of the force be proportional to any power whoſe index is $n-1$ of the diſtance, and if a be the diſtance from the fixed point at which the body begins to be accelerated, and x its diſtance from that point in any part of the motion, the velocity will be $\doteqdot\sqrt{a^n-x^n}$. This is very plain, becauſe the increment CGHD of the area of fig. 16. which is alſo the increment of the ſquare of the velocity, is $\doteqdot x^{n-1}\dot{x}$, and the area is $\doteqdot x^n$; and the whole area, correſponding to the diſtance a, is a^n. Therefore the portion of the area lying beyond the diſtance x is a^n-x^n. This is as the ſquare of the velocity, and therefore the velocity is as the ſquare root $\sqrt{a^n-x^n}$ of this quantity.

This propoſition, $f\dot{s}\doteqdot v\dot{v}$, or $f\doteqdot\frac{v\dot{v}}{\dot{s}}$, is the 39th of the firſt book of Newton's *Principia*, and is perhaps the moſt important in the whole doctrine of dynamics, whether employed for the inveſtigation of forces or for the explanation of motions. It furniſhes the moſt immediate data for both purpoſes, but more eſpecially for the laſt. By its help Sir Iſaac Newton was able to point out the numerous diſturbances of the planetary motions, and to ſeparate them from each other; thus unravelling, as it were, that moſt intricate motion in which all are blended together. He has given a moſt wonderful ſpecimen of its application in his Lunar Theory.

We now are able to explain all the puzzling facts which were adduced by Leibnitz and his partiſans in ſupport of their meaſure of the forces of bodies in motion. We ſee why four ſprings, equally bent, communicate but a double velocity, and nine ſprings but a triple velocity; why a bullet moving twice as faſt will penetrate an earthen rampart to a quadruple depth, &c. &c.

Conſervatio virium vivarum.

This theorem alſo gives a moſt perſpicuous explanation of the famous doctrine called *conſervatio virium vivarum.* When perfectly elaſtic bodies act on each other, it is found that the ſum of the maſſes multiplied by the ſquares of the velocities is always the ſame. This has been ſubſtituted, with great encomiums, by the German philoſophers in place of Des Cartes's principle, that the quantity of motion in the univerſe, eſtimated in one direction, remains always the ſame. They are obliged, however, to acknowledge, that in the actions of perfectly hard bodies, there is always a loſs of *vis viva*, and therefore have denied the exiſtence of ſuch bodies. But there is the ſame loſs in the mutual actions of all ſoft or ductile, or even imperfectly elaſtic, bodies; and they are miſerably puzzled how to explain the fact: but both the *conſervatio* and the *amiſſio* are neceſſary conſequences of this theorem.

In the colliſion of elaſtic bodies, the whole change of motion is produced during the ſhort time that the bodies are compreſſed, and while they regain their figure. When this is completed, the bodies are at the ſame diſtance from each other as when the mutual action began. Therefore the preceding body has been accelerated, and the following body has been retarded, along equal ſpaces; and in every point of this ſpace the accelerating and the retarding force has been equal. Conſequently the ſame area of fig. 17. expreſſes the change made on the ſquare of the velocity of both bodies. Therefore, if V and U are the velocities before colliſion, and v and u the velocities after colliſion, of the two bodies A and B, we muſt have $A\times\overline{V^2-v^2}=B\times\overline{u^2-V^2}$, and therefore $A\times V^2+B\times U^2=A\times v^2+B\times u^2$.

But in the other claſs of bodies, which do not completely regain their figure, but remain compreſſed, they are nearer to each other when their mutual action is ended than when it began. The foremoſt body has been accelerated along a ſhorter ſpace than that along which the other has been retarded. The mutual forces have, in every inſtant, been equal and oppoſite. Therefore the area, which expreſſes the diminution of the ſquare of the velocity, muſt exceed the area expreſſing the augmentation by a quantity that is always the ſame when the permanent compreſſion is the ſame; that is, when the relative motion is the ſame. $A\times\overline{V^2-v^2}$ muſt exceed $B\times\overline{u^2-U^2}$, and $A\times V^2+B\times U^2$ muſt exceed $A\times v^2+B\times u^2$.

This ſame theorem is of the moſt extenſive uſe in all practical queſtions in mechanic arts: and without it mechanics can go no further than the mere ſtatement of equilibrium.

Hiſtory of ° 95. is urious.

Hermann, profeſſor of mathematics at Pavia, one of the ornaments of the mathematical claſs of philoſophers, has given a pretty demonſtration of this valuable propoſition in the *Acta Eruditorum Lipſiæ* for 1709; and ſays, that having ſearched the writings of the mathematicians with great care, he found himſelf warranted to ſay, that Newton was the undoubted author, and boaſts of his own as the firſt ſynthetical demonſtration. The purpoſe of this aſſertion was not very apparent at the time; but long after, in 1746, when Hermann's papers, preſerved in the town-houſe of Pavia, were examined, in order to determine a diſpute between Maupertuis and Koenig about the claim to the diſcovery of *the principle of leaſt action*, letters of Leibnitz's were found, requeſting Hermann to ſearch for any traces of this propoſition in the writings of the mathematicians of Europe. Leibnitz was by this time the envious detractor from Newton's reputation; and could not but perceive, that all his contorted arguments for his doctrine received a clear explanation by means of this propoſition, in perfect conformity to the uſual meaſure of moving forces. Newton had diſcovered this theorem long before the publication of the *Principia*, and even before the diſcovery of the chief propoſition of that book in 1666: for in his optical Lectures, the materials of which were in his poſſeſſion in 1664, he makes frequent uſe of a propoſition founded on this (ſee n° 42.). We may here remark, that Hermann's demonſtration is, in every ſtep, the ſame with Dr Barrow's demonſtration of it as a theorem merely geometrical, without ſpeaking of moving forces (ſee *Lect. Geometr.* xi. p. 85. edit. 16.), but giving it as an inſtance of the tranſformation of curves, which he calls SCALES of velocity, of time, of acceleration, &c. It is very true that Barrow, in theſe mathematical lectures, approached very near to both of Newton's diſcoveries, the fluxionary geometry, and the principles of dynamics; and the junto on the continent, who were his continual detractors, charge him with impudent plagiariſm from Dr Barrow, and even ſay that he has added nothing to the diſcoveries of his teacher. But ſurely Dr Barrow was the beſt judge of this matter; and ſo far from reſenting the uſe which Newton has made of what he had taught him, he was charmed with the genius of the *juvenis ſpectatiſſimus* his ſcholar, and of his own accord gave him his profeſſorial chair, and ever after lived in the utmoſt harmony and friendſhip with him. Nay, it would even appear, from ſome expreſſions in thoſe very lectures, that Dr Barrow owed to young Newton the firſt thought of making ſuch extenſive uſe of motion in geomery. We recommend this work of Barrow's to the ſerious peruſal of our readers, who wiſh to acquire clear notions of the ſcience of motion, and an elegant taſte in their mechanical diſquiſitions. After all the cultivation of this ſcience by the commentators and followers of Newton, after the *Phoronomia* of Hermann, the *Mechanica* of Euler, the *Dynamique* of D'Alembert, and the *Mechanique Analytique* of De la Grange, which are undoubtedly works of tranſcendent merit and utility, the *Principia* of Newton will ſtill remain the moſt pleaſing, perſpicuous, and elegant ſpecimen of the application of mathematics to the ſcience of *univerſal mechanics*, or what we call DYNAMICS.

The two fundamental theorems $f\dot{t} = \dot{v}$, and $f\dot{s} = v\dot{v}$, enable us to ſolve every queſtion of motion accelerated or retarded by the action of the mechanical powers of nature. But the employment of them may be greatly expedited and ſimplified by noticing two or three general caſes which occur very frequently.

104 Similar inſtants and points, what?

Theſe may be called ſimilar inſtants of time, and *ſimilar points of ſpace which divide given portions of time*, and *of ſpace in the ſame ratio.* Thus the middle is a ſimilar inſtant of an hour or of a day, and is the ſimilarly ſituated point of a foot or of a yard. The beginning of the 21ſt minute, and of the 9th hour, are ſimilar inſtants of an hour and of a day. The beginning of the 5th inch, and of the 2d foot, are ſimilar points of a foot and of a yard.

105 Similar actions, what?

Forces may be ſaid to act ſimilarly when their intenſities in ſimilar inſtants of time, or in ſimilar points of ſpace, are in a conſtant ratio. Thus in fig. 17. when one body is impelled towards C from A, and another from K, each with a force proportional to the diſtance of every point of its motion from C, theſe forces may be ſaid to act ſimilarly along the ſpaces AC and KC, or during the times repreſented by the quadrantal arches AFH, KNO. The following propoſitions on ſimilar actions will be found very uſeful on many occaſions; but we muſt premiſe a geometrical lemma.

106 If there be two lines EFGH (fig. 18.), *efg h*, ſo related to their abſciſſes AD, *a d*, that the ordinates IK, *i k*, drawn from ſimilar points I and *i* of the abſciſſes, are in the conſtant ratio of AE to *a e*; then the area ADHE is to the area *a d h e* as the rectangle of AD × AE to the rectangle *a d* × *a e*.

For let each abſciſſa be divided into the ſame number of equal and very ſmall parts, of which let CD and *c d* be one in each. Inſcribe the rectangles CGID, *c g i d*. Then becauſe the number of parts in each axis is the ſame, the lengths of the portions CD and *c d* will be proportional to the whole abſciſſes AD and *a d*. And becauſe C and *c* are ſimilar points, CG is to *c g* as AE is to *a e*. Therefore $CD \times CG : cd \times cg = AD\ AE : ad \times ae$. This is true of each pair of correſponding rectangles; and therefore it is true of their ſums. But when the number of theſe rectangles is increaſed, and their breadth diminiſhed without end, it is evident that the ultimate ratio of the ſum of all the rectangles, ſuch as CDHG to the ſum of all the rectangles *c d h g* is the ſame with that of the area ADHE to the area *a d h e*, and the propoſition is manifeſt.

107 *If two particles of matter are ſimilarly impelled during given times, the changes of velocity are as the times and as the forces jointly.*

Let the times be repreſented by the ſtraight lines ABC (fig. 19.) and *a b c*, and the forces by the ordinates AD, BE, CF, and *a d*, *b e*, *c f*. Then if B and *b* are ſimilar inſtants (ſuppoſe the middles) of the whole times, we have $BE : be = AD : ad$. Therefore, by the lemma, the area ACFD is to *a c f d* as AC × AD to *ac* × *ad*. But theſe, areas are proportional to the velocities (n° 72), and the propoſition is demonſtrated. For the ſame reaſon, the change of velocity during the time AB is to the change during *a b* as AB × AD to *ab* × *ad*.

Cor. 1. If the times and forces are reciprocally proportional, the changes of velocity are equal; and if the forces are inverſely as the times, the changes of velocity are equal.

108 *If two particles be ſimilarly urged along given ſpaces, the changes made on the ſquares of the velocities are as the forces and ſpaces jointly.*

For if AC (fig. 19.) and *a c* are the ſpaces along which the particles are impelled, and the forces are as the ordinates AD and $a\,d$, the areas ACFD, and $a\,c\,f\,d$ are as the changes on the ſquares of the velocities. But theſe areas are as $\mathrm{AC}\times\mathrm{AD}$, and $ac\times ad$. Therefore, &c.

Cor. 2. If the ſpaces are inverſely as the forces, the changes of the ſquares of the velocities are equal; and if theſe are equal, the ſpaces are inverſely as the forces.

Cor. 3. If the ſpaces, along which the particles have been impelled from a previous ſtate of reſt, are directly as the forces, the velocities are alſo as the forces. For, becauſe the changes of the ſquares of the velocities are as the ſpaces and forces jointly, they are in this caſe as the ſquares of the forces or of the ſpaces; but the changes of the ſquares of the velocities are in this caſe the whole ſquares of the velocities; therefore the ſquares of the velocities are as the ſquares of the forces, and the velocities are as the forces. *N. B.* This includes the motions repreſented in fig. 17.

109 *If two particles be ſimilarly impelled along given ſpaces, from a ſtate of reſt, the ſquares of the times are proportional to the ſpaces directly, and to the forces inverſely.*

Let ABC (fig. 19.) $a\,b\,c$ be the ſpaces deſcribed, and AD, $a\,d$, the accelerating forces at A and a. Let V, B expreſs the velocity at B, and v, b the velocity at b.

Let GHK and $g\,h\,k$ be curves whoſe ordinates are inverſely as the velocities at the correſponding points of the abſciſſa. Theſe curves are therefore exponents of the times (n° 99.) Then, becauſe the forces act ſimilarly, we have, by the laſt theorem, $\mathrm{AC}\times\mathrm{AD} : a\,c\times a\,d = \underline{\mathrm{V}^2,\,\mathrm{B} :}\; v^2, b, \underline{= h\,b^2} : \mathrm{HB}^2$. Therefore $\mathrm{HB} : h\,b = \sqrt{ac\times a\,d} : \sqrt{\mathrm{AC}\times\mathrm{AD}}$ and therefore in a conſtant ratio. Call this the ratio of m to n. But, ſince the ordinates of the lines GHK, $g\,h\,k$ are inverſely as the velocities, the areas are as the times (n° 99); and ſince theſe ordinates are in the conſtant ratio of m to n, the areas are in the ratio of $\mathrm{AC}\times m$ to $a\,c\times n$. Therefore (calling the times of the motions T and t), we have

$$\mathrm{T} : t = m\,\mathrm{AC} : n\,a\,c\text{; and therefore}$$
$$\mathrm{T}^2 : t^2 = m^2\times\mathrm{AC}^2 : n^2\times a\,c^2.\quad\text{But}$$
$$m^2 : n^2 = a\,c\times a\,d : \mathrm{AC}\times\mathrm{AD}.\quad\text{Therefore}$$
$$\mathrm{T}^2 : t^2 = a\,c\times a\,d\times\mathrm{AC}^2 : \mathrm{AC}\times\mathrm{AD}\times a\,c^2,$$
$$\text{Or } \mathrm{T}^2 : t^2 = a\,d\times\mathrm{AC} : \mathrm{AD}\times a\,c.$$
$$\text{Or } \mathrm{T}^2 : t^2 = \frac{\mathrm{AC}}{\mathrm{AD}} : \frac{a\,c}{ad}.$$

The attentive reader will obſerve that theſe three propoſitions give a great extenſion to the theorems which were formerly deduced from the nature of uniformly accelerated motion, or of uniform action of the forces, and were afterwards demonſtrated to obtain in the momentary action of forces any how variable.

The firſt of the three propoſitions, $\mathrm{V} : v = \mathrm{F}\times\mathrm{T} : f\times t$, is the extenſion of the theorem $f\times\dot{t}=\dot{v}$. The ſecond, $\mathrm{V}^2 : v^2 = \mathrm{F}\times\mathrm{S} : f\times s$, is the extenſion of the theorem $f\times\dot{s}=v\,\dot{v}$. And the third, $\mathrm{T}^2 : t^2 = \frac{\mathrm{S}}{\mathrm{F}} : \frac{s}{f}$, is the extenſion of $f=\frac{\dot{s}}{(t^2)^{\cdot}}$, or of $f\times(t^2)^{\cdot}=\dot{s}$. Theſe theorems hold true of all *ſimilar* actions; and only for this reaſon, are true of uniformly accelerated motions, or uniform actions.

Aggreg of man equal ac lerating forces.

There remains one thing more to be ſaid concerning the action of accelerating forces. Their magnitude is aſcertained by their effect. Therefore that is to be conſidered as a double force which produces a double quantity of motion. Therefore when a body A contains twice the number of equal atoms of matter, and acquires the ſame velocity from the action of the force F that another body a, containing half the number of atoms, acquires from the action of a force f, we conceive F to be double of f. That this is a legitimate inference appears clearly from this, that we conceive the ſenſible weight of a body, or that preſſure which it exerts on its ſupports, as the aggregate of the equal preſſure, of every atom, accumulated perhaps on one point; as when the body hangs by a thread, and, by its intervention, pulls at ſome machine. Without inquiring in what manner, or by what intervention, this accumulation of preſſure is brought about, we ſee clearly that it reſults from the equal accelerating force of gravity acting immediately on each atom. When this weight is thus employed to move another body by the intervention of the thread, which is attached to one point perhaps of that body, it puts the whole into motion, generating a certain velocity v in every atom, by acting uniformly during the time t. We conceive each atom to have ſuſtained the action of an equal accelerating force, whoſe meaſure is $\frac{v}{t}$. Without conſidering how this force is exerted on each atom, or by what it is immediately exerted, or how it is diffuſed through the body from the point to which the weight of the other body is applied by means of the thread; we ſtill conſider it as the aggregate of the action of gravity on each atom of that other body. Moreover, attending only to the motion produced by it, and perhaps not knowing the weight of the impelling body, we meaſure it, as a moving force, by conſidering it as the aggregate of the forces propagated to each atom of the impelled body, and meaſured by $\frac{v}{t}$. If we know that the impelled body contains the number m of atoms, the aggregate of forces is $m\frac{v}{t}$, or $\frac{mv}{t}$.

But ſince we meaſure forces by the quantity of motion which they produce, we muſt conceive, that when the ſame force is applied to a body, which conſiſts of n particles, and produces the velocity u, by acting uniformly during the ſame time t, the force $n\frac{u}{t}$ is equal to the force $m\frac{v}{t}$.

11 Moving force, tive for vis mot as diſti guiſhed from a lerating force.

Sir Iſaac Newton found it abſolutely neceſſary, in the diſquiſitions of natural philoſophy to keep this circumſtance of acceleration clear of all notions of quantity of matter, or other conſiderations, and to contemplate the affections of motion only. He therefore conſidered $\frac{v}{t}$ as the true original meaſure of accelerating force, and $m\frac{v}{t}$ as an aggregate. He therefore calls the aggregate a *vis motrix*, a *moving force*, meaſured by the *quantity of motion* that it generates. And he confines the term *accelerating force* to the quantity $\frac{v}{t}$, meaſured by force; moſt commonly this is indicated by extrinſic circumſtances. The deflecting force is frequently obſerved to reſide in, or to accompany ſome other body. It may be preſumed, therefore, that it acts in the direction of the line drawn to or from that body; yet even this is uncertain. The moſt general rule for this inveſtigation is to obſerve the place of the body at ſeveral intervals of time before and after its paſſing through the point of the curve, where we are intereſted to find its preciſe direction. We then draw lines, joining thoſe places with the places of the tangent where the body would have been by the uniform motion only. We ſhall perhaps obſerve theſe lines of junction keep in parallel poſitions: we may be aſſured, that the direction of the tranſverſe force is the ſame with that of any of theſe lines. This is the caſe in the example juſt now given of a parabolic motion. But when theſe lines change poſition, they will change it gradually; and their poſition in the point of contact is that to which their poſitions on both ſides of it gradually approximate.

But all this is deſtitute of the preciſion requiſite in philoſophical diſcuſſion. We are indebted to Sir Iſaac Newton for a theorem which aſcertains the direction of the tranſverſe force with all exactneſs, in the caſes in which we moſt of all wiſh to attain mathematical accuracy, and which not only opened the acceſs to thoſe diſcoveries which have immortaliſed his name, but alſo pointed out to him the path he was to follow, and even marked his firſt ſteps. It therefore merits a very particular treatment.

114 Newton's fundamental theorem for the direction of a deflecting force.

If a body deſcribes a curve line ABC, DEF (fig. 21.) lying in one plane; and if there be a point S ſo ſituated in this plane that the line joining it with the body deſcribes areas ASB, ASC, ASD, &c. proportional to the times in which the body deſcribes the arches AB, AC, AD, &c. the force which deflects the body from rectilineal motion is continually directed to the fixed point S.

Let us firſt ſuppoſe that the body deſcribes the polygon ABCDEF, &c. formed of the chords AB, BC, CD, DE, EF, &c. of this curve: and (for greater ſimplicity of argument) let us conſider areas deſcribed in equal ſucceſſive times; that is, let us ſuppoſe that the triangles ASB, BSC, CSD, &c. are equal, and deſcribed in equal times. Make B *c* = AB, and draw *c* S.

Areas ≑ to the times indicate central forces.

Had the motion AB ſuffered no change in the point B, the body would have deſcribed B *c* in the equal moment ſucceeding the firſt: but it deſcribes BC. The body has therefore been deflected by an external force; and BC is the diagonal of a parallelogram (n° 45. 46.), of which B *c* is one ſide, and *c* C is another. The deflecting force will be diſcovered, both in reſpect of direction and intenſity, by completing the parallelogram B *c* C *b*. B *b* is the ſpace which the deflecting force would have cauſed the body to deſcribe in the time that it deſcribes B *c* or BC. Becauſe B *c* is equal to BA, the triangles BS *c*, BSA are equal. But (by the nature of the motion) BSA is equal to BSC. Therefore the triangles BSC and BS *c* are equal. They are alſo on the ſame baſe BS; therefore they lie between the ſame parallels, and C *c* is parallel to SB. But *c* C is parallel to B *b*. Therefore B *b* coincides with BS, and the deflecting force at B is directed toward S. By the ſame argument, the deflecting force at the angles D, E, F, &c. is directed to S.

Now, let the ſides of the polygon be diminiſhed, and their number increaſed without end. The demonſtration remains the ſame; and continues, when the polygon finally coaleſces with the curve, and the deflection is continual.

When areas are deſcribed proportional to the times, equal areas are deſcribed in equal times; and therefore the deflection is always directed to S. Q. E. D.

Centre of deflection. Centre of forces. Central forces.

The point S may, with great propriety of language, be called the CENTRE OF DEFLECTION, or THE CENTRE OF FORCES; and forces which are thus continually directed to one fixed point, may be diſtinguiſhed from other deflecting forces by the name CENTRAL FORCES.

The line joining the centre of forces with the body, and which may be conceived as a ſtiff line, carrying the body round, is uſually named the RADIUS VECTOR.

Radius vector.

115 Central forces produce areas proportional to the times.

The converſe of this propoſition, *viz.* that if the deflecting forces be always directed to S, the motion is performed in one plane in which S is ſituated, and areas are deſcribed proportional to the times—is eaſily demonſtrated by reverſing the ſteps of this demonſtration. The motion will be in the plane of the lines SB and B *c*; becauſe the diagonal BC of the parallelogram of forces is in the plane of the ſides. Areas are deſcribed proportional to the times; for C *c* being parallel to SB, the triangles SCB and S *c* B are equal; and therefore SCB and SAB are equal, &c. &c.

116 Velocity is inverſely as the perpendicular from the centre.

Cor. 1. When a body deſcribes areas round S proportional to the times, or when it is continually deflected toward S, or acted on by a tranſverſe force directed to S, the velocities in the different points A and E of the curve are inverſely proportional to the perpendiculars S *r* and S *t*, drawn from the centre of forces to the tangents in thoſe points; that is, to the perpendiculars from the centre on the momentary directions of the motion: For ſince the triangles ASB, ESF are equal, their baſes AB, EF are inverſely as their altitudes S *r*, S *t*. But theſe baſes, being deſcribed in equal times, are as the velocities; and they ultimately coincide with the tangents at A and E.

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Cor. 2. If $B\alpha$ and $F\varepsilon$ be drawn perpendicular to SA and SE, we have $SA \times B\alpha = SE \times F\varepsilon$, and $SA : SE = F\varepsilon : B\alpha$: For $SA \times B\alpha$ is double of the triangle BSA; and $SE \times F\varepsilon$ is double of the equal triangle SFE.

118 Angular velocity is inverſely as the ſquare of the diſtance from the centre of forces.

Cor. 3. The angular velocity round S, that is, the magnitude of the angle deſcribed in equal times by the radius vector, is inverſely proportional to the ſquare of the diſtance from S. For when the arches AB, EF are diminiſhed continually, the perpendiculars $B\alpha$ and $F\varepsilon$ will ultimately coincide with arches deſcribed round S with the radii SB and SF. Now the magnitude of an angle is proportional to the length of the arch which meaſures it directly, and to the radius of the arch inverſely. In any circle, an arch of two inches long meaſures twice as many degrees as an arch one inch long; and an arch an inch long contains twice as many degrees of a circle whoſe radius is twice as ſhort. Therefore, ultimately, the angle ASB is to the angle ESF as $B\alpha$ to $F\varepsilon$, and as SF to SB jointly; that is, as $B\alpha \times SF$ to $F\varepsilon \times SB$. But $B\alpha : F\varepsilon = SE : SA$ (*Cor.* 2.). Therefore $ASB : ESF = SE \times SF : SB \times SA$, $=$ ultimately $SE^2 : SB_2$.

This corollary gives us an oſtenſible mark, in many very important caſes, of the action of a deflecting force being always directed to a fixed point. We are often able to meaſure the angular motion when we cannot meaſure the real velocities.

Intimate connection of dynamics and the higher geometry.

Having thus diſcovered the chief circumſtances which enable us to aſcertain the direction of the deflecting force, we proceed to inveſtigate the quantity of this deflective determination in the different points of a curvilineal motion. This is a more difficult taſk. The momentary effect of the deflecting force is a ſmall deviation from the tangent; and this deviation is made with an accelerated motion. The law of this acceleration regulates the curvature of the path, and is to be determined by it. We may be allowed to obſerve by the way, that it appears clearly from the form in which Newton has preſented all his dynamical theorems, that we are indebted to theſe problems for the immenſe improvement which he has made in geometry by his invention of fluxions. The purpoſes he had in view ſuggeſted to his penetrating mind the means for attaining them; and the connection between dynamics and geometry is ſo intimate, that the ſame theorems are in a manner common to both. This is particularly the caſe in all that relates to curvature. Or ſhall we ſay that the geometry of Dr Barrow ſuggeſted the dynamical theorems to Newton? We have ſeen how the curvature of a parabola is produced by a force acting uniformly. The *momentary* action of all finite forces may be conſidered as uniform; and therefore the curvature will be that of ſome portion of ſome parabola; but it will be difficult to determine the preciſe degree without ſome farther help. We are beſt acquainted with the properties of the circle, and will have the cleareſt notions of the curvature of other curves by comparing them with circles.

Meaſure of curvature.

The curvature of a circular arch of given length is ſo much greater as its radius is ſhorter; for it will contain ſo many more degrees in the ſame length; and therefore the change of direction of its extremities is ſo much greater. Curvatures may always be meaſured by the length of the arch directly and the radius inverſely.

119
Evolution and involution of curves.

Suppoſe a thread made faſt at one end of a material curve ABCD (fig. 22.) and applied to it in its whole length. Taking hold of its extremity D, unfold it gradually from the curve DCBA; the extremity D will deſcribe another curve D *c b a*. This geometrical operation is called the Evolution of curves, and D *c b a* is called the Evolute of DCBA, which is called the Involute of D *c b a*. Perhaps this denomination has been given from the geneſis of the area, or ſurface contained by the two lines which is folded up and unfolded ſomewhat like a fan. When the deſcribing point is in *b*, the thread *b* B is, undoubtedly, the momentary radius of a circle *e b f*, whoſe centre is B, the point of the involute which it is juſt going to quit. The momentary motion of *b* is the ſame, whether it is deſcribing an arch of the evolute paſſing through *b*, or an arch of a circle round the centre B. The ſame line *b t*, perpendicular to the thread *b* B, touches the circle *e b f* and the curve D *b a* in the point *b*. This circle *e b f* muſt lie within the curve D *b a* on the ſide of *b* B toward *a*; becauſe on this ſide the momentary radius is continually increaſing. For ſimilar reaſons, the circle *e b f* lies without the curve on the other ſide of *b* B. Therefore the circle *e b f* both touches and cuts the curve D *b a* in the point *b*. Moreover, becauſe every portion of the curve between *b* and D is deſcribed with radii that are ſhorter than *b* B, it muſt be more incurvated than any portion of the circle *e b f*. For ſimilar reaſons, every portion of the curve between *b* and *a* muſt be leſs incurvated than this circle; therefore the circle has that preciſe degree of curvature that belongs to the curve in the point *b*; it is therefore called the Equicurve Circle, or the Circle of Curvature, and B is called the centre, and B *b* the Radius of Curvature. It is eaſy to perceive that no circle can be deſcribed which ſhall touch the curve in *b*, and come between it and the circle *e b f*; for its centre muſt be in ſome point *i* of the radius *b* B. If *i b* be leſs than B *b*, it muſt fall within the curve on both ſides of *b*, and if *i b* is greater than B *b*, the circle muſt fall without the curve on both ſides of B *b*. The circle *e b f* lies cloſer to the curve, has cloſer contact with it, than any other, and has therefore got the whimſical name of Osculating Circle; and this ſort of contact was called Osculation.

Circle of curvature.
Equicurve circle.

This view of the geneſis of curve lines is of particular uſe in dynamical diſcuſſions. It exhibits to the eye the perfect ſameneſs of the momentary motion, and therefore of the momentary deflection, in the curve and in the equicurve circle, and leaves the mind without a doubt but that the forces which produce the one will produce the other. A great variety of curves may be deſcribed in this way. If perpendiculars be drawn to the curve D *b a* in every point, they will interſect each other, each its immediate neighbour, in the circumference of the curve DBA; and geometry teaches us how to find the curve DBA which ſhall produce the curve D *b a* by evolution (ſee Evolution and Involution, *Supplement*).

It is a matter worthy of remark, that the path of a body that is deflected from rectilineal motion by a *finite* force, varying according to any law whatever, may always be deſcribed by evolution. This includes almoſt every caſe of the action of deflecting forces; none being excepted but when, by the oppoſite action of different forces, the body is in equilibrio in one ſingle point of its path.

Our taſk is now brought within a very narrow compaſs, namely, to meaſure the deflection in the arch of a circle.

Had the motion repreſented in fig. 21. been polygonal, it is plain that the deflecting force in the point B is to that in the point E as the diagonal B *b* of the parallelogram ABC *b* to the diagonal E *i* of the parallelogram DEF *i*; therefore let ABCZY be a circle paſſing through the points A, B, and C, and let the radius vector BS cut the circumference in Z; draw AZ, CZ, and the diagonal AC, which neceſſarily biſects and is biſected by the diagonal B *b*. The triangles *b* BC and CBZ are ſimilar; for the angle C *b* B is equal to the alternate angle AB *b* or ABZ, which is equal to the ACZ, ſtanding on the ſame chord AZ. And the angle CB *b*, or CBZ, is equal to CAZ, ſtanding on the ſame chord CZ; therefore the remaining angle *b* CB is equal to the remaining angle AZC; therefore ZA is to AC as BC to B *b*, and B *b* $=\frac{AC\times BC.}{AZ}$ In like manner E *i* $=\frac{DF\times EF.}{Dz}$

Now let the points A and C continually approach, and ultimately coaleſce with B; it is evident that the circle ABCZY is ultimately the equicurve or coinciding circle at the point B, and that AS ultimately coaleſces with, and is equal to, BS, and that AC × BC is ultimately 2BC^2; therefore ultimately $\text{B}\,b : \text{E}\,i = \frac{2\text{BC}^2}{\text{BZ}} : \frac{2\text{EF}^2}{\text{E}\,z}$, or $= \frac{\text{BC}^2}{\frac{1}{2}\text{BZ}} : \frac{\text{EF}^2}{\frac{1}{2}\text{E}\,z}$.

Meaſure of deflecting forces.

Now BC and EF, being deſcribed in equal times, are as the velocities: B *b* and E *i* are the meaſures of the velocities which the deflective forces at B and E would generate in the time that the body deſcribes BC or EF, and are therefore the meaſures of thoſe forces. *They are as the ſquares of the velocities directly, and inverſely as thoſe chords of the equicurve circles which have the directions of the deflection.*

Obſerve, that B *b* or E *i* is the third proportional to half of the chord and the arch deſcribed; for $\text{B}\,b : \text{BC} = \text{BC} : \frac{\text{BZ}}{2}$.

It is evident, that as the arches AB, BC, continually diminiſh, AC is ultimately parallel to the tangent B *r*, and BO is equal to the actual deflection from the tangent. The triangles BOC and AOZ are ſimilar, and $\text{BO} = \frac{\text{OC}^2}{\text{OZ}}$, or ultimately $= \frac{\text{BC}^2}{\text{BZ}}$. We may meaſure the forces by the actual deflections, becauſe they are the halves of the meaſures of the generated velocities; and we may ſay that

120
Meaſure of deflection.

The actual momentary deflection from the tangent is a third proportional to the deflective chord of the equicurve circle and the arch deſcribed during the moment.

Caution.

Either of theſe meaſures may be taken, but we muſt take care not to confound them. The firſt is the moſt proper, becauſe the change produced on the body (which is the *immediate* effect and meaſure of the force) is the determination, left inherent in it, to move with a certain velocity. This is the meaſure alſo which we obtain by means of the differential or fluxionary calculus; but the other meaſure muſt be obtained when our immediate object is to mark the actual path of the body. What is now delivered coincides with what was more briefly ſtated in ASTRONOMY, *Suppl.* n° 16. and is repeated in this place, becauſe the ſteps of this demonſtration, which is Newton's, ſo naturally terminate in the equicurve circle, and give at once the immediate meaſure of the deflecting force: at the ſame time the reader muſt perceive that this meaſure does not depend on the force being always directed to one centre; it is enough that the two ſides of the polygon, in immediate ſucceſſion, are deſcribed in equal times. This is neceſſary in order that AB*Cb* may be a parallelogram, and that the diagonals AC and B *b* may mutually biſect each other.

Thus have we obtained a meaſure of deflecting force, and, in the moſt important caſes, a method of diſcovering its direction. It only remains to point out the relation between the intenſity of the force, the curvature of the path, and the velocity of the motion. Theſe three circumſtances have a neceſſary connection; for we ſee that the intenſity is expreſſed by certain values of the other two in the formula $f \doteq \frac{\text{Arch}^2}{\frac{1}{2}\text{Chord}}$, or $f = \frac{2\,\text{BC}^2}{\text{BZ}}$. The deflective velocity B *b* is acquired in the time that the body deſcribes BC; therefore the deflective velocity is to the velocity in the curve as B *b* to BC. The velocity B *b* is acquired by an accelerated motion along BO; for while, by progreſſive motion, the body deſcribes BC, it deflects from the tangent through a ſpace equal to the half of B *b*, becauſe the momentary action of the deflecting force may be conſidered as uniform. The progreſſive velocity BC may be generated by the ſame force, uniformly acting through a ſpace greater than BC; call this ſpace *x*. The ſpaces along which a body muſt be uniformly impelled in order to acquire different velocities, are as the ſquares of thoſe velocities; therefore $\text{B}\,b^2 : \text{BC}^2 = \text{B}\,o : x$; but $\text{B}\,b : \text{BC} = \text{BC} : \frac{1}{2}\text{BZ}$; therefore $\text{B}\,b^2 : \text{BC}^2 = \text{B}\,b : \frac{1}{2}\text{BZ}$, and $\text{B}\,b : \frac{1}{2}\text{BZ} = \text{B}\,o : x$, and $\text{B}\,b : \text{B}\,o = \frac{1}{2}\text{BZ} : x$; but B *o* is $\frac{1}{2}$ of B *b*; therefore *x* is $\frac{1}{4}$ of BZ; that is,

The velocity in any point of a curvilineal path, is that which the deflecting forces in that point would generate in the body by impelling it uniformly along one fourth part of the deflective chord of the equicurve circle. 121

If the velocity increaſe, the chord of the equicurve circle muſt increaſe: that is, the path becomes leſs incurvated. If the force be increaſed, the curvature will alſo increaſe, for the chord of curvature will be leſs.

There is another general obſervation to be made on the velocity of a curvilineal motion, which greatly aſſiſts us in our inveſtigations.

122
Compariſon of orb tal motion with direc approacht the centre.

If a body deſcribes a curve by the action of a force always directed to a fixed point, and varying according to any proportion whatever of the diſtances from that point, and if another body, acted on by the ſame centripetal force, move toward the centre in a ſtraight line, and if in any one caſe of equal diſtances from the centre of force the two bodies have equal velocities, they will have equal velocities in every other caſe of equal diſtances from the centre.

Let one body be impelled from A (fig. 23.) toward C along the ſtraight line AVDEC, and let another be deflected along the curve line VIK *k*. About the centre C deſcribe concentric arches ID, KE, very near to each other, and cutting the curve in I and K, and the line AC in D and E; draw IC, cutting KE in N, and draw NT perpendicular to the arch IK of the curve, and complete the parallelogram ITNO. Let the bodies be ſuppoſed to have equal velocities at I and at D.

Then, becauſe the centripetal forces are ſuppoſed to be the ſame for both bodies when they are at equal diſtances, the accelerating forces at D and I may be repreſented by the equal lines DE and IN; but the force IN is not wholly employed in accelerating the body along the arch IK, but, acting tranſverſely, it is partly employed in incurvating the path. It is equivalent to the two forces IO and IT, of which only IT accelerates the body. Now IKN is a right angled triangle, as is alſo the triangle INT; and they are ſimilar; therefore IN : IT = IK : IN, or DE : IT = IK : DE; that is, the force which accelerates the body along DE is to the force which accelerates the body along IK as the ſpace IK is to the ſpace DE; therefore (n° 86.) the increment of the ſquare of the velocity acquired along DE is equal to the increment of the ſquare of the velocity acquired along IK. But the velocities at D and I were equal, and conſequently their ſquares were equal; and theſe having received equal increments, therefore the ſquares of the velocities at E and K are equal, and the velocities themſelves are equal. And ſince this is the caſe in all the correſponding points of the line AC and the curve VIK, the velocities at all equal diſtances from C will be equal.

It is evident that the concluſion will be the ſame, if the bodies, inſtead of being accelerated by approaching the centre in the ſtraight line AC, and in the curve VIK, are moving in the oppoſite directions from E to A, or from I to V, and are therefore retarded by the centripetal force.

123 Retarded curvilineal motion always accompanied by receſs from the centre.

Cor. Hence it follows, that if a body be projected from any point, ſuch as V, of the curve, in a line tending ſtraight from the centre, with the velocity which it had in that point of the curve, it would go to a diſtance VA, ſuch, that if it were impelled along AV by the centripetal force, it would acquire its former velocity in the point V; alſo in any point between V and A it will have the ſame velocity in its receſs from the centre that it has there in its approach to the centre.

The line BLFG, whoſe ordinates are as the intenſities of the centripetal force in A, V, D, E, or in A, V, I, K, may be called the SCALE OR EXPONENT of force; the areas bounded by the ordinates AB, VL, DF, EG, &c. drawn from any two points of the axis, are as the ſquares of the velocity acquired by acceleration along the intercepted part of the axis, or in any curvilineal path, while the body approaches the centre, or which are loſt while the body retires from it. When we can compute theſe areas we obtain the velocities (ſee n° 102.).

We are now in a condition to ſolve the chief problem in the ſcience of dynamics, to which the whole of it is, in a great meaſure, ſubſervient. The problem is this,

124 Inverſe problem of centripetal forces.

Let a body be projected with a known velocity from a given point and in a given direction, and let it be under the influence of a mechanical force, whoſe direction, intenſity, and variation, are all known: it is required to determine its path, and its motion in this path, for any given time?

This problem is ſuſceptible of three diſtinct claſſes of conditions, which require different inveſtigation.

1. The force may act in one conſtant direction; that is, in parallel lines.

2. The force may be always directed to a fixed point.

3. It may be directed to a point which is continually changing its place.

1. When the force acts in parallel lines, the problem is ſolved by compounding the rectilineal accelerated motion which the force would produce in its own direction with the uniform motion which the projection alone would have produced. The motion muſt be curvilineal, when the accelerating force is tranſverſe, in any degree whatever, to the projectile motion; and the curvilineal path muſt be concave on that ſide to which the deflecting force tends; for the force is ſuppoſed to act inceſſantly. The place of the body will be had for any time, by finding where the body would have been at the end of that time by each force acting alone, and by completing the parallelogram. Thus, ſuppoſe a body projected along AB (fig. 20.) while it is continually acted on by a force whoſe direction is AD. Let D and B be the places where the body would be at the end of a given time. Then the body will, at the end of that time, be in F, the oppoſite angle of the parallelogram ABFD. But it has not deſcribed the diagonal AF, becauſe its motion has been curvilineal, as we ſhall find by determining its place at other inſtants of this time.

The velocity in any point F is found by firſt determining the velocity at D, and making DT to DF as the velocity at D to the velocity at B (that is, the velocity of projection, becauſe the motion along AB is uniform). Then draw TF. Then AB is to TF as the conſtant velocity of projection to the velocity at F. We have ſeen already (n° 112—119.) that TF is a tangent to the curve in F. Hence we may determine the velocity at F in another way. Having determined the form of the path in the way already deſcribed, by finding its different points, draw the tangent F d, cutting the line DA in d. Then the velocity at A is to that at F as AB to d F. Hence alſo we ſee, that the velocities in every point of the curve are proportional to the portion of the tangents at thoſe points which are intercepted between *any* two lines parallel to AD.

Either of theſe methods for aſcertaining the velocity, in this caſe of parallel deflections, will in general be eaſier than the general method in n° 121. by the equicurve circle.

It was thus that Galileo diſcovered the parabolic motion of heavy bodies.

Inverſe problem of centripetal forces.

2. We muſt conſider the motions of bodies affected by centripetal or centrifugal forces, always tending to one fixed point. This is the celebrated *inverſe problem of centripetal forces*, and is the 42d propoſition of the firſt book of Newton's *Principia*. We ſhall give the ſolution after the manner of its illuſtrious author; becauſe it is elementary, in the pureſt ſenſe of the word, keeping in view the two leading circumſtances, and theſe only, namely, the motion of approach and receſs from the centre, and the motion of revolution. By this judicious proceſs, it becomes a pattern by which more refined, and, in ſome reſpects, better ſolutions ſhould be modelled. At the ſame time we ſhall ſupply ſome ſteps of the inveſtigation which his elegant conciſeneſs has made him omit.

125

Let a body, which tends to C (fig. 24.) with a force proportional to the ordinates of the exponent BLFG, having the axis CA, be projected from V in the direction VQ, with the velocity which the centripetal force would generate in it by accelerating it along AV. It is required to determine the path or orbit VIKI of the body, and its place I in this orbit, at the end of the aſſigned time T?

Suppoſe the thing done, and that I is the place of the body. About the centre C, with the diſtances CV and CI, deſcribe the circles YV and ID. Draw CIX to the circumference, and draw the ordinate DF of the exponent of forces, producing it toward x, and produce the ordinate VL toward a. Let V t be the diſtance to which the body would go along the tangent VQ in the Time T and join t C. Let this be ſuppoſed done for every point of the curve. Let $a\ i\ k$ and $a\ x\ y$ be two curves ſo related to the curve VIK, that the ordinate DF cuts off an area V $a\ i$ D equal to the orbital ſector VCI, and an area V $a\ x$ D equal to the circular ſector VCX.

Then, becauſe the velocity of projection is given, the diſtance V *t* is known, and the area of the triangle VC*t*. But this is equal to the area VCI, by the laws of central forces (n° 115.). Therefore the area V *a i* D is given. Alſo, becauſe the area VCI increaſes in the proportion of the time, the area V *a i* D increaſes at the ſame rate. Therefore, having theſe ſubſidiary curves *a i k*, *a x y*, the problem is ſolved as follows:

Draw an ordinate D *i*, cutting off an area V *a i* D proportional to the time, and deſcribe a circle DIR. Then draw a line CX, cutting off a ſector VCX, equal to the area V *a x* D cut off by the ordinate D *i x*. This line will cut the circle DR in the point I, which is the point of the orbit that was demanded.

But the chief difficulty of the problem conſiſts in the deſcription of the two ſubſidiary curves *a i k* and *a x y*, into which the lines VIK, and VXY are transformed. We attain this conſtruction by reſolving the motion in the arch of the orbit into two motions, one of which is in the direction of the tranſverſe force, or of the radius vector, and the other is in the direction of revolution, or perpendicular to the radius.

Let V *k* and IK be two very ſmall arches deſcribed in equal moments, and therefore ultimately in the ratio of the velocities in V and I (n° 73.). Deſcribe the circle KE, cutting IC in N. Draw KC and *k* C, and *k n* perpendicular to VC.

The element ICK of the orbit is $=\frac{\mathrm{IC}\times\mathrm{KN}}{2}$, or to $\frac{1}{2}$ IC × KN. This is equal to the element D *i k* E of the area V *a i* D, or to $\mathrm{D}\,i\times\mathrm{DE}$, or to $\mathrm{D}\,i\times\mathrm{IN}$. Therefore $\mathrm{IN}:\mathrm{KN}=\frac{1}{2}\,\mathrm{IC}:\mathrm{D}\,i$, or $2\,\mathrm{IN}:\mathrm{KN}=\mathrm{IC}:\mathrm{D}\,i$, and $\mathrm{D}\,i=\frac{\mathrm{IC}\times\mathrm{KN}}{2\,\mathrm{IN}}$.

Now let A *l f g h* be the exponent of the velocities, that is (n° 86.), let $\mathrm{V}\,l^2$ be to $\mathrm{D}f^2$ as ABLV to ABFD, or $\mathrm{V}\,l:\mathrm{D}f=\sqrt{\mathrm{ABLV}}:\sqrt{\mathrm{ABFD}}$. Make V *v* and I *i* in the tangents reſpectively equal to V *l* and D *f*. Draw *v u* and *i o* perpendicular to VC and IC, and *v m* perpendicular to LV produced. Let *m r z* be an equilateral hyperbola, having VC, ZC, for its aſſymptotes, and cutting FD produced in *r*. Then the ordinates V *m*, D *r*, are inverſely proportional to CV, CD, or $\mathrm{V}\,m:\mathrm{D}\,r=\mathrm{CD}:\mathrm{CV},=\mathrm{CI}:\mathrm{CV}$. But becauſe the momentary ſectors VC *k* and ICK are equal, $k\,n:\mathrm{KN}=\mathrm{CI}:\mathrm{CV}$. Therefore,

$\mathrm{V}\,m:\mathrm{D}\,r=k\,n:\mathrm{KN}$
but $\mathrm{V}\,v:\mathrm{V}\,m=\mathrm{V}\,k:k\,n$
and $\mathrm{I}\,i\ (\text{or }\mathrm{D}f):\mathrm{V}\,v=\mathrm{IK}:\mathrm{V}\,k$
therefore $\mathrm{I}\,i:\mathrm{D}\,r=\mathrm{IK}:\mathrm{KN}$
but $\mathrm{I}\,i:i\,o=\mathrm{IK}:\mathrm{KN}$, by ſim. triang.

Therefore $\mathrm{D}\,r=i\,o$, and $i\,o:\mathrm{V}\,m=\mathrm{VC}:\mathrm{CI}$.

Alſo, by ſimilarity of triangles, $\mathrm{I}\,o:i\,o=\mathrm{IN}:\mathrm{KN}$, and $2\,\mathrm{I}\,o:i\,o=2\,\mathrm{IN}:\mathrm{KN}$.

Now it was ſhewn, that in order that the ſpace D *i k* E may be equal to the ſpace ICK, we muſt have

$2\,\mathrm{IN}:\mathrm{KN}=\mathrm{IC}:\mathrm{D}\,i$
or $2\,\mathrm{I}\,o:i\,o=\mathrm{IC}:\mathrm{D}\,i$
but $i\,o:\mathrm{V}\,m=\mathrm{VC}:\mathrm{IC}$
therefore $2\,\mathrm{I}\,o:\mathrm{V}\,m=\mathrm{VC}:\mathrm{D}\,i$
and $\mathrm{D}\,i=\frac{\mathrm{VC}\times\mathrm{V}\,m}{2\,\mathrm{I}\,o}$.

Having obtained D *i*, we eaſily get D *x*: for the ultimate ratio of ICK to XCY is that of IC^2 to VC^2. Therefore make

$$\mathrm{IC}^2:\mathrm{VC}^2=\mathrm{D}\,i:\mathrm{D}\,x.$$

Thus are the points of the two ſubſidiary curves *a i k*, *a x y*, determined.

The rectangle VC × V *m* is a conſtant magnitude; and is given, becauſe VC is given, and V *m* is the given velocity V *l*, diminiſhed in the ratio of radius to the ſine of the given angle CVQ.

But the line 2 I *o* is of variable magnitude, but it is alſo given, by means of known quantities. $\mathrm{I}\,o^2$ is $=\mathrm{I}\,i^2-i\,o^2,=\mathrm{D}f^2-\mathrm{D}\,r^2$, and $\mathrm{I}\,o=\sqrt{\mathrm{D}f^2-\mathrm{D}r^2}$. Moreover, $\mathrm{D}f^2=\mathrm{ABFD}$, and $\mathrm{D}\,r^2=\frac{\mathrm{VC}^2\times\mathrm{V}\,m^2}{\mathrm{IC}^2}$.

Therefore $2\,\mathrm{I}\,o=2\sqrt{\mathrm{ABFD}-\frac{\mathrm{VC}^2\times\mathrm{V}\,m^2}{\mathrm{IC}^2}}$, expreſſed in known quantities, becauſe ABFD is known from the nature of the centripetal force.

Let the indeterminate diſtance CI or CD be $=x$, and let the ordinate DF, expreſſing the force, be *y*. Let VC be *a*, and V *m* be *c*, and let *a b* be a rectangle equal to the whole area of the exponent of force lying between the ordinate AB and the ordinate CZ, ſo that $a\,b-\int y\,\dot{x}$ may repreſent the indeterminate area ABFD.

We have $\mathrm{D}\,i=\frac{a\,c}{2\sqrt{a\,b-\int y\,\dot{x}-\frac{a^2c}{x^2}}}$

and $\mathrm{D}\,x=\frac{a^3c}{2\,x^2\sqrt{a\,b-\int y\,\dot{x}-\frac{a\,c^2}{x^2}}}$.

Remark. We have hitherto ſuppoſed that the velocity of projection is acquired by acceleration along AV. But this was merely for greater ſimplicity of argument, and that the final values of D *i* and D *x* might be eaſier conceived. In whatever way the velocity is acquired, it will ſtill be true, that when in any point V we make V *l* to V *m* as the momentary increment V *k* of the arch is to the perpendicular *k n* on the radius vector, we ſhall have in every other point, ſuch as I, the line D *f* to the line D *r* as the increment IK of the arch to KN. And in the final equation D *f* will ſtill be expreſſed by $\sqrt{a\,b-\int y\,\dot{x}}$.

126 *Cor.* 1. The angle which the path of the projectile makes with the radius vector is determined by this ſolution; for I *i* is to *i o* as radius to the ſine of this angle; which ſine is therefore $=\frac{a\,c}{x\sqrt{a\,b-\int y\,\dot{x}}}$.

127 *Cor.* 2. When the magnitude $\frac{a\,c}{x}$ is equal to $\sqrt{a\,b-\int y\,\dot{x}}$, the path is perpendicular to the radius vector, and the body is a tone of the apſides of its orbit, and begins to recede from the centre after having approached to it, or begins to opproach after having receded.

Apſides determined;

128 And curvature.

Cor. 3. The curvature of the orbit VIK is alſo determined in every point; for the curvature of any line is inverſely as the radius of the equicurve circle, and this is to the chord which paſſes through C as radius to the

DYNAMICS, PLATE XXIII.

Fig. 21.

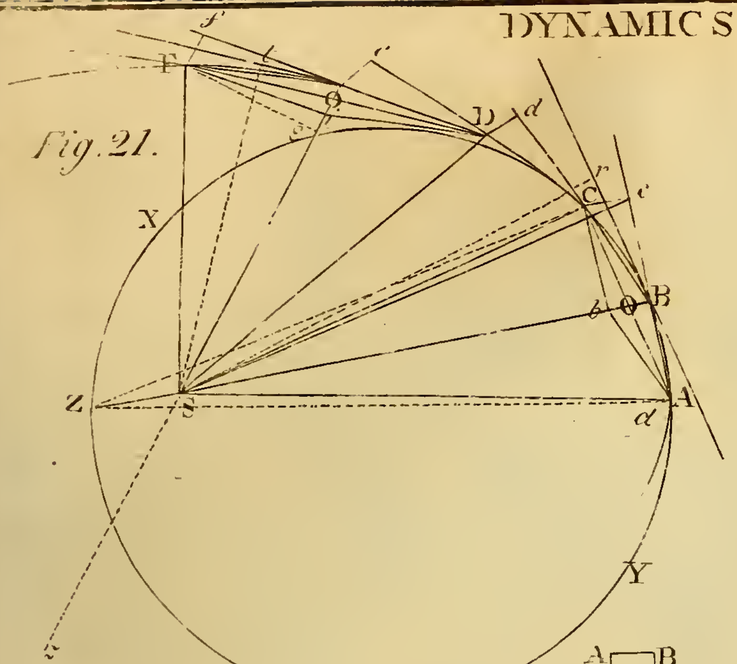


Fig. 24.

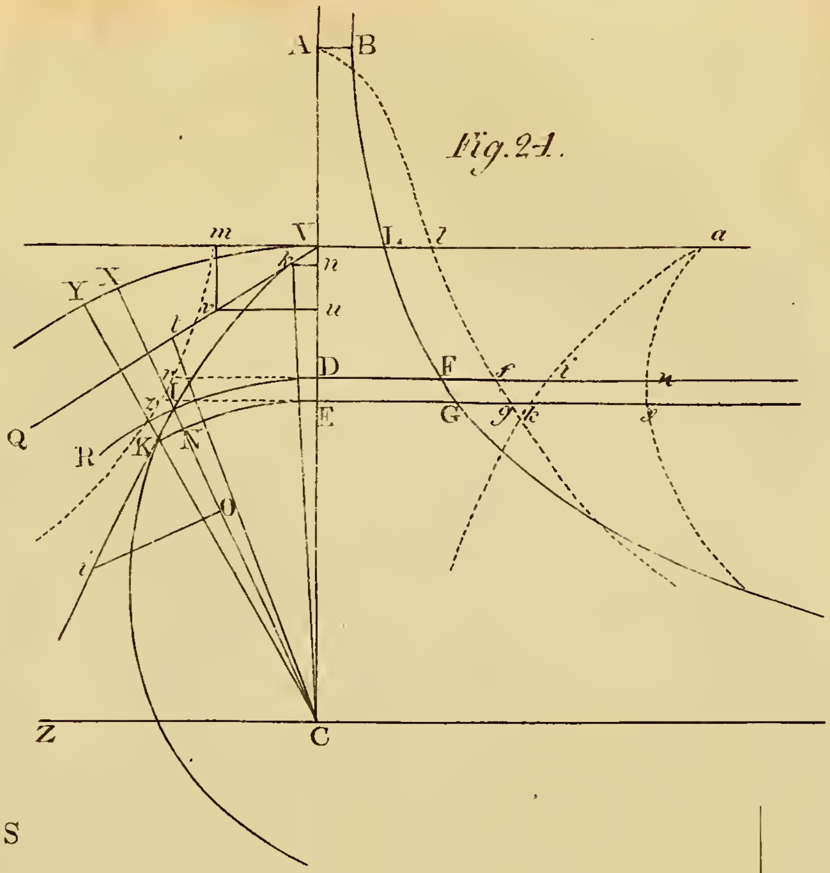


Fig. 23.

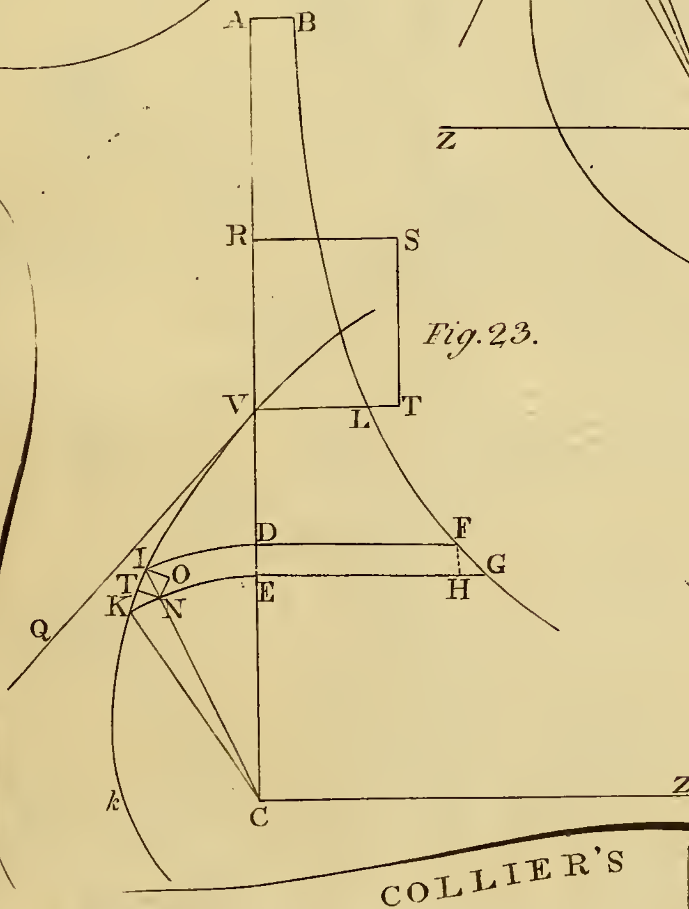
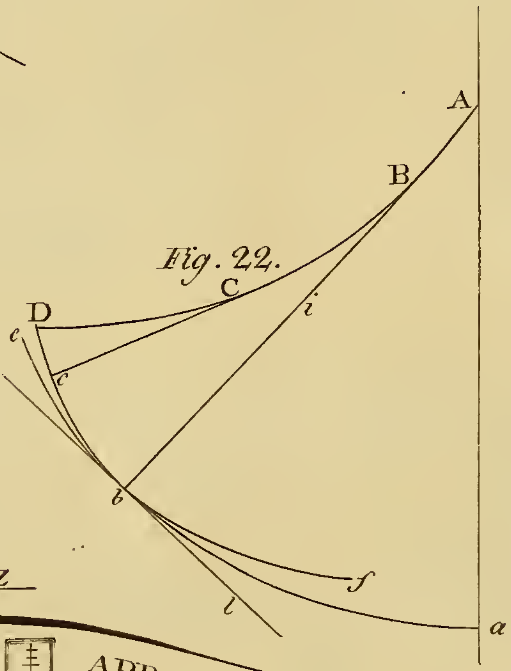
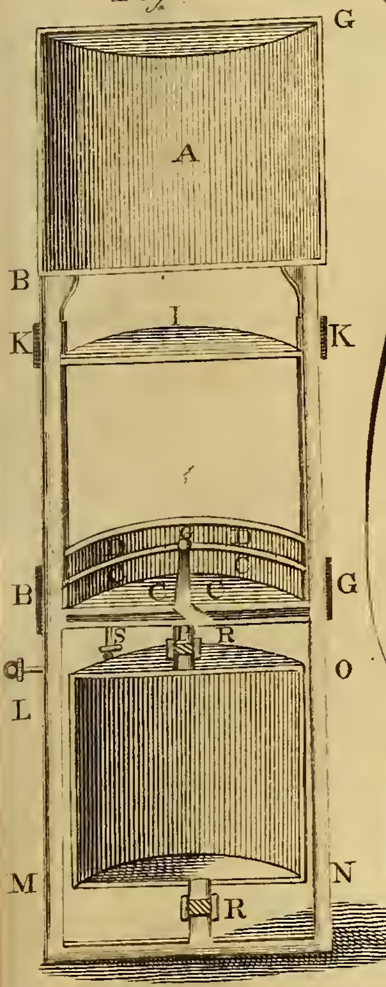


Fig. 22.



COLLIER'S APPARATUS.

Fig. 1.



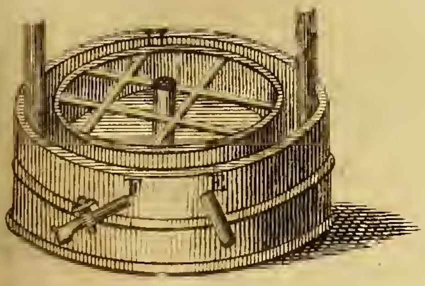
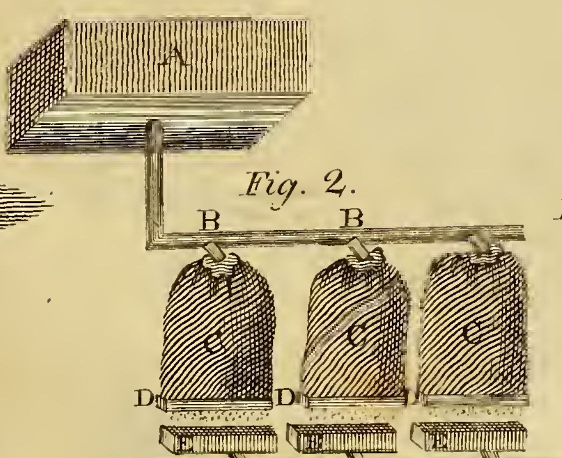


Fig. 2.



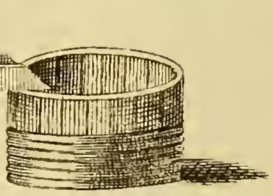


Fig. 4.

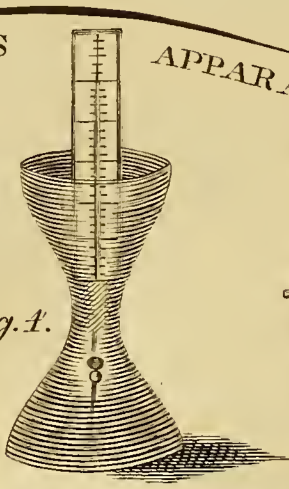
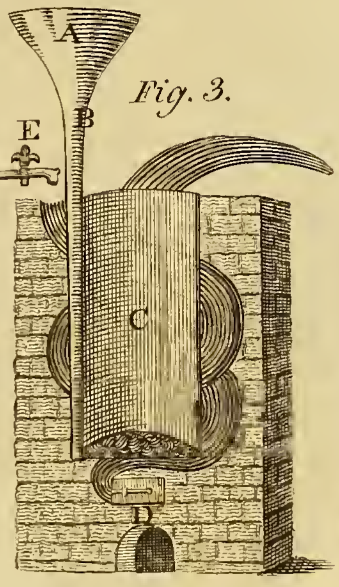


Fig. 3.



Jones sc.

the ſine of the angle CI *i*. Becauſe the velocity in any point I is $= \sqrt{\text{ABFD}}$, and is equal to what the centripetal force at I would produce, by impelling the body along $\frac{1}{4}$th of the deflective chord of the equicurve circle, we have this chord $= 4\,\frac{\text{ABFD}}{\text{DF}}$. Or we obtain it by taking a third proportional to the momentary deflection and the momentary arch of the curve, or by other proceſſes of the higher geometry, all proceeding on the quantities furniſhed in this inveſtigation.

129 Newton the inventor.

Such is the ſolution of this celebrated problem given by Sir Iſaac Newton, who may juſtly be called the inventor of the ſcience of which it is the chief reſult, as well as of the geometry, by help of which it is proſecuted. For we cannot give this glory to Galileo; for his ſimple problem of the motion of bodies affected by uniform and parallel gravity, however juſt and elegant his ſolution may be, was peculiar; and the ſame muſt be ſaid of Mr Huyghens's doctrine of centrifugal forces. Beſides, theſe theorems had been inveſtigated by Newton ſeveral years before, *ſuâ matheſi facem preferente*, as corollaries which he could not paſs unnoticed, from his general method. This is proved by letters from Huygens. Newton's inveſtigation is extremely, but elegantly, conciſe, and is one of the beſt exertions of his ſagacious mind.

130 Hiſtory of his problem.

Whether we conſider this problem as a piece of mere mathematical ſpeculation, or attend to its conſequences, which include the whole of the celeſtial motions in all their extent and complication, we muſt allow it to be highly intereſting, and likely to engage much attention in the period of ardent inquiry which cloſed the laſt century. Accordingly, it was no ſooner known, by the publication of the *Mathematical Principles of Natural Philoſophy* in 1686, than it occupied the talents of the moſt eminent mathematicians; and many ſolutions were publiſhed, ſome of which differ conſiderably from Newton's; ſome are more expeditious, and better fitted for computation. Of theſe, the moſt remarkable for originality and ingenuity are thoſe of de Moivre, Hermann, Keill, and Stewart. The laſt differs moſt from the methods purſued by others. M'Laurin's propoſitions on this ſubject, and in that part of his fluxions which treats of curvature, are highly valuable, claſſing the chief affections of curvilineal motions geometrically, as they are ſuggeſted by the fluxionary method; and then ſhewing, in a very inſtructive manner, the connection between theſe mathematical affections of motion and the powers of nature which produce them. This part of his excellent work is a fine example of the real nature of all inquiries in dynamics; ſhewing that it differs from geometry little more than in the language, in which the word *force* is ſubſtituted for *acceleration*, *retardation*, or *deflection*. We recommend the careful peruſal of theſe propoſitions to all who wiſh to have clear conceptions of the ſubject. Dr John Keill and Dr Horſeley (biſhop of Rocheſter) have given particular treatiſes on the motions of bodies deflected by centripetal forces inverſely proportional to the cubes of the diſtances; induced by the ſingular motions which reſult from this law of action, and the multitude of beautiful propoſitions which they ſuggeſt to the mathematician. Newton, indeed, firſt perceived both of theſe peculiarities, and has begun this branch of the general problem. He firſt demonſtrated the deſcription of the logarithmic and hyperbolic ſpirals, and indicated a variety of curious recurring elliptical ſpirals, which would be deſcribed by means of this force, and ſhewing that they are all ſuſceptible of accurate quadrature. Several of thoſe authors affect to conſider their ſolutions as more perfect than Newton's, and as more immediately indicating the remarkable properties of ſuch motions; and alſo affect to have deduced them from different and original principles. But we cannot help ſaying, that their claims to ſuperiority are very ill founded; there is not a principle made uſe of in their ſolutions which was not pointed out by Newton, and employed by him. The appearance of originality ariſes from their having taken a more particular concern in ſome general property of curvilineal motions; ſuch as the curvature, the centrifugal force, &c. and the making that the leading ſtep of their proceſs. But Newton's is ſtill the beſt; becauſe it is ſtrictly elementary, aiming at the two leading circumſtances, the motion to or from the centre, and the motion of revolution round that centre. To theſe two purpoſes he adapted his two ſubſidiary curves. This procedure became Newton, *pater, et rerum inventor*, who was teaching the world, and who might ſay,

> *Avia Pieridum peragro loca, nullius ante*
> *Trita pede*——

Singular boaſt of John Bernoulli.

Is it not ſurpriſing, that 25 years after the publication of Newton's *Principia*, a mathematician on the continent ſhould publiſh a ſolution in the Memoires of the French academy, and boaſt that he had given the firſt demonſtration of it? Yet John Bernoulli did this in 1710. Is it not more remarkable that this ſhould be preciſely the ſolution given by Newton, beginning from the ſame theorem, the 40th I. Prin. following Newton in every ſtep, and uſing the ſame ſubſidiary lines? Yet ſo it is. Bernoulli actually reduces the whole to two functions; namely, $\dfrac{ac}{\sqrt{ab - \int \varphi\, \dot{x} - \frac{a^2 c^2}{x^2}}}$ and $\dfrac{a^2 c}{\sqrt{a b x^4 - \int \varphi\, x^4 - a^2 c^2 x^2}}$; which laſt is plainly the ſame with Newton's $\dfrac{\text{Q} \times \text{CX}^2}{\text{A}^2 \sqrt{\text{ABDF} - \text{Z}^2}}$; becauſe Newton's $\frac{\text{Q}}{\text{A}}$ is the ſame with $\frac{ac}{x}$, and Newton's $\text{A}^2 \sqrt{\text{ABFD} - \text{Z}^2}$ is the ſame with $x^2 \sqrt{ab - \int \varphi\, \dot{x} - \frac{a^2 c^2}{x^2}}$, which Bernoulli has changed (apparently to hide the borrowing) into $\sqrt{a b x^4 - \int \varphi\, x^4\, \dot{x} - a^2 c^2 x^2}$. This publication of Bernoulli is perhaps the moſt impudent piece of literary *robbery*, for theft is too mild a term, that has ever appeared; and is the more deſerving of ſevere reprehenſion, becauſe it is full of reflections on the ſimple and ſupremely elegant method of Newton. It is hardly conceivable that a perſon of Bernoulli's conſummate mathematical knowledge was ſo much blinded by the mechanical procedure of the ſymbolical calculus (which indeed is rarely accompanied by any ideas of the ſubject in hand) as not to perceive the perfect ſameneſs of his ſolution. No; he ſhews, from time to time, that the phyſical ideas of motion and force were preſent to his mind; for he affects to ſhew, that all Newton's brighteſt diſcoveries, ſuch as the proportionality of the areas and times, &c. flow as corollaries from his procedure.

Bernoulli's chief boaſt in this diſſertation is, that *now* philoſophers may be aſſured that the planets will always deſcribe conic ſections; a truth of which they had not as yet received any proof: becauſe, ſays he, Newton's argument for it in the corollary of the 13th propoſition is inconcluſive, and becauſe he had not been able to accommodate his demonſtration of the 41ſt and 42d propoſition to the particular caſe of the planetary gravitation. Two aſſertions that border on inſolence. Newton's demonſtration in the corollary of the 13th propoſition is juſt, founded on the principle on which the very demonſtration of the 42d, adopted by Bernoulli, proceeds, and without which that demonſtration is of no force; namely, that a body, in given circumſtances of ſituation, velocity, direction, and centripetal force, can deſcribe no other figure than what it really deſcribes. Newton did not accommodate the demonſtration of the 42d propoſition to the planetary motions, becauſe he had already demonſtrated the nature of their orbits; but mentions the caſe of a force proportional to the reciprocal of the cubes of the diſtance; not as a deduction from the 42d, but becauſe it *was not* a deduction from it, and admitted a very ſingular and beautiful inveſtigation by methods totally and eſſentially different.

Bernoulli alſo ſays, that Newton's ſolution does not give us the notion of a continuous path, as his own does, but only informs us how to aſcertain points of this path. This is the boldeſt of all his aſſertions. Bernoulli uſes the differential calculus. It is the *eſſential* character of this calculus that it exhibits, and *can* exhibit, nothing but detached points. This is undeniable. And this has been objected to Newton's firſt propoſition. But Newton's fluxionary *geometry*, of which the calculus exhibits only elements (being the ſame with the differential), ſuppoſes the continuity of all magnitudes; and when applied to dynamics, is no ſubſtitution whatever, but the *ipſa corpora*. This geometry offered itſelf to the mind of Newton, the accompliſhed and darling ſcholar of Barrow, whoſe geometry flaſhed on Newton's mind as the torch which was to ſhew him the ſteps of this yet untrodden path.

We truſt that our readers will not be diſpleaſed with our repeated endeavours to defend our great philoſopher from the injurious attacks that have been made on him. During his own illuſtrious life, while he was diffuſing light and knowledge around him, and never contended for fame, happy in being the inſtructor of mankind, he was injured by thoſe who envied his reputation, while they derived their chief honours from being his beſt commentators. Now, ſince he has left this world, he has been more groſsly injured by thoſe who avail themſelves of that very reputation; and who, by crude and contemptible inferences from his doctrine of elaſtic undulations, and groſs miſrepreſentations of his notions of an etherial fluid, have pretended to ſupport a ſyſtem of materialiſm; and thus have ſet Newton at the head of the atheiſtical ſect, which he held in abhorrence. For our part, we always think with pleaſure on the wonderful energy of that great mind; becauſe it gives us a foretaſte of thoſe pleaſures that await the wiſe and good, when the ſorrows flowing from the infirmities, the vices, and the arrogant vanity of man are paſt;

Utque in hoc infelici campo,
Ubi luctus regnat, et pavor,
Mortalibus prorſus non abſit ſolatium.
Hujus enim ſcripta evolvas,
Mentemque tantarum rerum capacem
Corpori caduco ſuperſtitem credas.

131 Concluſion.

It cannot be expected that, in the narrow limits preſcribed to a work like ours, we can proceed to conſider the various departments of this celebrated problem. We are only giving the outlines of the general doctrines of dynamics; and we have beſtowed more time on thoſe which are purely elementary than ſome readers may think they deſerve. We were anxious to give juſt conceptions of the fundamental principles of dynamics; becauſe we know that nothing elſe can intitle it to the name of a demonſtrative ſcience, and becauſe we ſee much indiſtinctneſs and uncertainty, and a general vagueneſs or want of preciſion, in ſeveral elementary works which are put into the hands of perſons entering on the ſtudy. This leads to errors of more conſequence than a perſon is apt to think; becauſe they effect our leading thoughts of mechaniſm itſelf, and our notions of the intimate nature of the viſible univerſe.

132 Reaſons for omiſſions.

But we muſt conclude the article with this great problem. Many very general doctrines of dynamics remain untouched; all, namely, that relate to the rotative motion of rigid bodies, and all that relate to the mutual action of bodies on each other in the way of impulſe.

The rotative motions, with the doctrine of mechanic momenta, have been conſidered at large in the article ROTATION of the *Encycl.* and we propoſe to offer ſome important conſiderations on the ſame ſubject in our ſupplement to the articles MACHINE and MECHANICS. In the article IMPULSION will be conſidered ſuch doctrines as are truly general, and independent of the ſpecific differences of the bodies. DYNAMICS profeſſes to involve no notions but thoſe of force, and its marks and meaſures.

Notwithſtanding theſe great omiſſions, we muſt obſerve that no new principle remains to be conſidered. We have given all that are neceſſary; and there is no queſtion that occurs in the caſes omitted, which cannot be completely anſwered by means of the propoſitions already eſtabliſhed. We have taught how to diſcover the exiſtence and agency of a mechanical force, to meaſure and characteriſe it, and then to ſtate what will be its various effects, according to the circumſtances of the caſe.

133 *Univerſal reaction* is a law of the material world.

Proceeding by theſe principles, men have diſcovered an univerſal fact, that every ACTION of one body on another is accompanied by an equal REACTION of that other on the firſt, in the oppoſite direction; that is, to expreſs it in the language of dynamics, "all the phenomena which make us infer that the body A poſſeſſes a force by which it changes the motion of the body B, ſhew, at the ſame time, that B poſſeſſes a force by which it makes an equal and oppoſite alteration in the motion of A." This, however, is not a doctrine of abſtract dynamics: it does not flow from our idea of force; therefore it was not included in our liſt of the LAWS OF MOTION. It is a part of the mechanical hiſtory of nature, juſt as the law of univerſal gravitation is; and it might be called the law of UNIVERSAL REACTION. Sir Iſaac Newton has, in our humble apprehenſion, deviated from his accuſtomed logical accuracy, when he admits, as a third *axiom* or law of motion, that reaction is always equal and contrary to action. It is a phyſical law, in as far as it is *obſerved* to obtain through the whole extent of the ſolar ſyſtem. But Newton himſelf did not, in the ſubſequent part of his noble work, treat it as a logical axiom; that is, as a law of human thought with reſpect to motion: for he labours with much ſolicitude, and with equal ſagacity, to prove, by *fact and obſervation*, that it really obtains through the whole extent of the ſolar ſyſtem; and it is in this diſcovery that his chief claim to unequalled penetration and diſcernment appears.

134 Impulſion explained by it;

Availing ourſelves of this fact, we, with very little trouble, ſtate all the laws of impulſion. The body A, for example, moving to the weſtward at the rate of eight feet per minute, overtakes the double body B, moving at the rate of four feet per minute. What muſt be the conſequence of their mutual impenetrability, and of the equality and contrariety of action and reaction? Their motions muſt be ſuch that both ſuſtain equal and oppoſite changes. They muſt give, in ſome way or other, *this* indication of poſſeſſing equal and oppoſite forces. This will be the caſe if, when the changes are completed, A and B move on in contact at the rate of four feet per minute: for here A has produced in each half of B a change of motion two; and therefore a totality of change equal to four. This is the effect, the mark, the meaſure, of the *impulſive* force of A; for it is the whole *impulſion*. B has produced in A a change of motion four, equal to the former, and in the oppoſite direction. This is the effect, mark, and meaſure of the *repulſive* force of A; for it is the whole *repulſion*. And this is all that we obſerve in the colliſion of two lumps of clay; and the obſervation is one of the facts on which the reality of the phyſical law of equal action and reaction is founded: and we can make no farther inference from *this* fact.

But the event might have been very different. A and B may be two magnets floating on corks on water, with their north poles fronting each other. We know, by other means, that they really poſſeſs forces by which they equally repel each other. The dynamical principles already eſtabliſhed tell us alſo what muſt happen in this caſe. That both conditions of equal reaction and ſenſible repulſion may be fulfilled, A muſt come to reſt, and B muſt move forward at the rate of four feet per minute. The ſame thing muſt happen in the meeting of perfectly elaſtic bodies, ſuch as billiard balls. If elaſticities are known to be imperfect in any degree, our dynamical principles will ſtill ſtate the effect of their colliſion, in conformity to the law of equal reaction.

135 And rotation.

In like manner, all the motions of rotation are explained or predicted by means of the ſame principles of dynamics applied to the force of coheſion. This is conſidered as a moving force, becauſe, when the attraction of a magnet acts on a bit of iron attached to one end of a long lath floating on water, the whole lath is moved, although the magnet does not act on it at all: ſome other force acts on it; it is its coheſion; which is therefore a moving force, and the ſubject of dynamical diſcuſſion.

136 And thus it appears that theſe ſubjects do not come neceſſarily, nor, perhaps, with ſcientific propriety, under the category of dynamics, but are parts of the mechanical hiſtory of nature. Yet, did a work like ours give room in this place, the ſtudy of mechanical nature might be conſiderably improved, by giving a ſyſtem of ſuch *general* doctrines as involve no other notions but thoſe of force and its meaſures, and the hypotheſis of equal reaction. Some very general, nay univerſal, conſequences of this combination might be eſtabliſhed, which would greatly aſſiſt the mechanician in the ſolution of difficult and complicated problems. Such is the propoſition, that *the mutual actions of bodies depend on their relative motions only, and require no knowledge of their real motions.* This principle ſimplifies in a wonderful manner the moſt difficult and the moſt frequent caſes of action which nature preſents to our view; but at the ſame time gives a ſevere blow to human vanity, by forcing us to acknowledge that we know nothing of the real motion of any thing in the univerſe, and never ſhall know any thing of it, till our intellectual conſtitution, or our opportunities of obſervation, are completely changed.

137 Mr D'Alembert has made this principle ſtill more ſerviceable for extricating ourſelves from the immenſe complication of actions that occurs in all the ſpontaneous phenomena of nature, by preſenting it to us in a different form, which more diſtinctly expreſſes what may be called the *elements* of the actions of bodies on each other. His propoſition is as follows (*ſee his Dynamique*, page 73.):

D'Alembert's general principle of dynamics.

"In whatever manner a number of bodies change their motions, if we ſuppoſe that the motion which each body would have in the following moment, if it were perfectly free, is decompoſed into two others, one of which is the motion which it really takes in conſequence of their mutual actions, the other will be ſuch, that if each body were impreſſed by this force alone (that is, by the force which would produce this motion) the whole ſyſtem of bodies would be in equilibrio."

This is almoſt ſelf-evident; for if theſe ſecond conſtituent forces be not ſuch as would put the ſyſtem in equilibrio, the other conſtituent motions could not be thoſe which the bodies really take by the mutual action, but would be changed by the firſt.

For example, let there be three bodies P, Q, R, and let the forces A, B, C, act on them, ſuch as would give them the velocities p, q, r, in any directions whatever, producing the momenta, or quantities of motion, $P\times p$, $Q\times q$, $R\times r$, which we may call A, B, C, becauſe they are the proper meaſures of the moving force. Let us moreover ſuppoſe, that, by ſtriking each other, or by being any how connected with each other, they cannot take theſe motions A, B, and C, but really take the motions a, b, and c. It is plain that we may conceive the motion A impreſſed on the body P, to be compoſed of the motion a, which it really takes, and of another motion α. In like manner, B may be reſolved into b, which it takes, and another β; and C into c and $\varkappa$. The motions will be the ſame whether

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when the original itſelf is in our hands, and affords a much more comprehenſible object than one of its abſtract qualities, mere magnitude. Let any perſon candidly compare the lunar theory by Mayer or Euler with that by its illuſtrious inventor Sir Iſaac Newton, and ſay which of the two is moſt luminous and moſt pleaſing to the mind. No perſon will deny that theſe later performances are incomparably more adapted to all practical purpoſes, and lead to corrections which it would be extremely difficult and tedious to inveſtigate geometrically; but it muſt be acknowledged, at the ſame time, that *till this be done*, we have no idea whatever of the deviation of the tract which this correction aſcertains from the path which the moon would follow, independent of the diſturbance expreſſed by the correction. In like manner, Dan. Bernoulli, by mixing as much as poſſible the linear method with the algebraic, in his diſſertations on muſical chords, made the beautiful diſcovery of the ſecondary trochoids, and demonſtrated the co-exiſtence of the harmonic ſounds in a full muſical note. Let the accompliſhed mathematician puſh forward our knowledge of dynamics by the employment of the ſymbolical analyſis; but let him be followed as cloſe as poſſible by the geometer, that we may not be robbed of ideas, and that the ſtudent may have light to direct his ſteps. But,—*manum e tabulâ.*

Dynanometer.

DYNANOMETER, an inſtrument for aſcertaining the relative muſcular ſtrength of men and other animals. That it would be deſirable to know our relative ſtrengths at the different periods of life, and in different ſtates of health, will hardly be denied; and there can be no doubt but that it would be highly uſeful to have a portable inſtrument by which we could aſcertain the relative ſtrength of horſes or oxen intended for the plough or the waggon. Such an inſtrument was invented, many years ago, by Graham, and improved by Deſaguliers; but being conſtructed of wooden work it was too bulky to be portable, and therefore it was limited in its uſe.

M. Leroy of the Academy of Sciences at Paris conſtructed a much more convenient Dynanometer than Graham's, conſiſting of a metal tube ten or twelve inches in length, placed vertically on a foot like that of a candleſtick, and containing in the inſide a ſpiral ſpring, having above it a graduated ſhank terminating in a globe. This ſhank, together with the ſpring, ſunk into the tube in proportion to the weight acting upon it, and thus pointed in degrees the ſtrength of the perſon who preſſed on the ball with his hand.

This was a very ſimple conſtruction, and, we think, a good one; but it did not ſatisfy Buffon and Gueneau. Theſe two philoſophers wiſhed not merely to aſcertain the muſcular force of a finger or a hand, but to eſtimate that of each limb ſeparately, and of all the parts of the body. They therefore employed M. Regnier to contrive a new *dynanometer;* and the account which he gives* of his attempts to fulfil their wiſhes is calculated to enhance the difficulty of the enterprize. The inſtrument, however, which he conſtructed is not ſuch as appears to us to have required any uncommon ſkill in mechanics, or any very great ſtretch of thought. It conſiſts chiefly of an elliptical ſpring twelve inches in length, rather narrow, and covered with leather that it may not hurt the fingers when compreſſed by the hands. This ſpring is compoſed of the beſt ſteel well welded and tempered, and afterwards ſubjected to a ſtronger effort than is likely to be ever applied to it either by men or animals, that it may not loſe any of its elaſticity by uſe.

The effects of this machine are eaſily explained. If a perſon compreſſes the ſpring with his hands, or draws it out lengthwiſe by pulling the two extremities in contrary directions, the ſides of the ſpring approach towards each other; and it has an apparatus (we do not think a very ſimple one) appended to it, conſiſting of an index and ſemicircular plate, by which the degree of approach, and conſequently of effort, employed, is aſcertained with great accuracy. The author gives a tedious deſcription of other appendages, by means of which horſes or oxen may be employed to compreſs the ſpring. But as any mechanic may deviſe means for this purpoſe, we do not think it worth while to tranſcribe that deſcription. The Engliſh reader will find a full account of the whole apparatus in the 4th number of the very valuable miſcellany entitled *The Philoſophical Magazine*. The principle of the contrivance, conſiſts in the elliptical ſpring, of which we confeſs ourſelves unable to perceive the ſuperiority to the ſpiral ſpring of M. Leroy, though the author ſees it very clearly.

Dyſentery.

DYSENTERY (See MEDICINE *Index*, Encycl.). For the cure of this diſeaſe we have the following ſimple preſcription by Dr Perkins and Dr B. Lynde Oliver, of the ſtate of Maſſachuſetts in North America.

Saturate any quantity of the beſt vinegar with common marine ſalt; to one large table ſpoonful of this ſolution add four times the quantity of boiling water; let the patient take of this preparation, as hot as it can be ſwallowed, one ſpoonful once in half a minute until the whole is drank: this for an adult. The quantity may be varied according to the age, ſize, and conſtitution of the patient. If neceſſary, repeat the doſe once in ſix or eight hours. Conſiderable evacuations I conceive (ſays Dr Perkins) to be not only unneceſſary, but injurious, as they ſerve to debilitate and prolong the diſeaſe. A tea of plantain, or ſome other cooling, ſimple drink, may be uſeful; and if a thirſt for cyder be diſcovered, it may be gratified. Carefully avoid keeping this preparation in veſſels partaking of the qualities of lead or copper, as the poiſon produced by that means may prove dangerous.

The ſucceſs of the remedy depends much on preparing and giving the doſe as above directed.—The ſimplicity of this treatment renders it the more valuable, as all perſons have it in their power to avail themſelves of its uſe.

Dr Perkins ſays, that he has found it uſeful in agues, diarrhœas, and the yellow fever.

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* *Journal de l'Ecole Polytechnique*, v. 2.

E.

EARL, a townſhip in Lancaſter co. Pennſylvania.—*Morse.*

EARTH, in chemiſtry. See CHEMISTRY-*Index* in this Supplement.

EARTH, in aſtronomy and geography. See *Encyclopædia.*

EARTH, in ancient philoſophy, one of the elements, the ſubſtance of which this globe is compoſed. To aſcertain the denſity of that ſubſtance many experiments have been made; but perhaps none more ingenious than thoſe of Mr Cavendiſh, which are detailed at full length in Part II. of the Tranſactions of the Royal Society of London for 1798. They were projected by the late Rev. John Michell, F. R. S. but he did not live to carry them into effect. After his death the apparatus came to the Rev. F. J. H. Wollaſton, Jackſonian Profeſſor at Cambridge, who transferred them to Mr Cavendiſh. The apparatus contrived for making ſenſible the attraction of ſmall quantities of matter, and which has been improved by Mr Cavendiſh, is very ſimple: it conſiſts of a wooden arm 6 feet long, ſuſpended by the middle in an horrizontal poſition by a ſlender wire 40 inches long; to each extremity is hung a leaden ball about two inches in diameter; and the whole is incloſed in a wooden caſe to defend it from the wind.

As no more force is required to turn this balance on its centre than is neceſſary to twiſt the ſlender ſuſpending wire, the ſmalleſt degree of attraction of a leaden weight or weights, a few (eight) inches in diameter, brought near to the ſmall ſuſpended ball or balls of the balance, will be ſufficient to move it ſenſibly aſide.

To determine from hence the denſity of the earth, all that is neceſſary is, to aſcertain what force is required to draw the arm aſide through a given ſpace, and then to have recourſe to calculation.

To prevent any diſturbance from currents that might be produced within the box that contained the balance, by even the difference of temperature that might be occaſioned by heat being communicated by the bodies of the experimenters to one ſide of it more than another, it was ſupported in the middle of a cloſe room; the operators, from adjoining apartments, viewed the operation through holes in the wall by means of teleſcopes; and the apparatus had a ſtrong light thrown upon its two ends (an opening being left at each end of the box for the purpoſe) by means of two lamps, alſo in the adjoining apartments, the rays from which were likewiſe made to paſs through the holes formed in the wall.

The two large balls were ſuſpended from a beam near the cieling, which could be moved in an horrizontal direction, by means of a ſtring and pulley, ſo as to be brought near to the ſmall balls of the balance, or made to recede again, without requiring any perſon to be in the room.

From this deſcription it will be eaſily ſeen, that on the two large balls being brought near to the two ſmall ones, but on oppoſite ſides of each, that their forces may not counteract each other—the ſmall ſuſpending wire of the balance muſt be twiſted by the movements of the arms, occaſioned by attraction, which carries the ſmall towards the large balls; and that the wire, endeavouring to untwiſt itſelf, will again in its turn carry the ſmall balls away from the large ones. Vibrations are thus occaſioned, which would continue a long time before the ſmall balls would ſettle between the firſt point of reſt and the large balls: but it is not neceſſary to wait for this; an ivory ſcale at each end of the balance enables the experimenters, by means of their teleſcopes, to ſee the two extreme diviſions to which the ſmall balls move in their vibrations, and thus to determine the middle point. The time neceſſary for each vibration is alſo noticed.

A full account of theſe experiments, and of the calculations founded on them, would be little intereſting to the great majority of our readers. We ſhall therefore only mention the reſult. By a mean of the experiments the denſity of the earth comes out 5·48 times greater than that of water.

By the experiments made by Dr Maſkelyne on the attraction of the hill Schehallien, the denſity of the earth was computed to be only 4½ times that of water. The difference of reſult, therefore, is almoſt one-fifth, which no doubt muſt leſſen our confidence in either ſet of experiments, or in the principle on which they were deviſed.

Earth-Worm (ſee LUMBRICUS, *Encycl.*) is an animal which occaſions ſuch deſtruction in gardens, by gnawing the tender roots of ſhrubs and plants, that various methods have been propoſed for remedying this evil. One of the lateſt, and that which promiſes to prove the moſt ſucceſsful, is given by M. SOCOLOFF in the fifth volume of the New Tranſactions of the Imperial Academy of Sciences at Peterſburgh. As the deſtructive power of quick-lime, heightened by a fixed alkali, which corrods or diſſolves all the tender parts of animals, has been long known, it occurred to our author that this mixture would be the beſt means for accompliſhing the object which he had in view. He therefore took three parts of quick-lime, newly made, and two parts of a ſaturated ſolution of fixed alkali in water, and thence obtained a ſomewhat milky liquor ſufficiently cauſtic, highly hoſtile and poiſonous to earth-worms and other ſmall animals; for as ſoon as it touched any part of their bodies, it occaſioned in them violent ſymptoms of great uneaſineſs. If this liquor be poured into thoſe holes in which the earth-worms reſide under ground, they immediately throw themſelves out as if driven by ſome force; and, after various contorſions, either languiſh or die. If the leaves of plants or fruit-trees, frequented by the voracious caterpillars, which are ſo deſtructive to them, be ſprinkled over with this liquor, theſe inſects ſuddenly contract their bodies and drop to the ground. For though Nature has defended them tolerably well by their hairy ſkins from any thing that might injure their delicate bodies, yet as ſoon as they touch with their feet or mouths leaves which have been moiſtened by this liquor, they become as if it were ſtupified, inſtantly contract themſelves, and fall down.

With regard to plants or corn, theſe ſuſtain no injury from the liquor, becauſe it has no power over the productions of the vegetable kingdom, as our author has fully learned from experience ; or if any hurt is to be ſuſpected, all the danger will be removed by the firſt ſhower that falls. This liquor may be procured in abundance in every place where lime is burnt. If the lime be freſh, one part of it infuſed into about ſeventy parts of common water will produce real lime-water. The want of the fixed alkali may be ſupplied by boiling wood aſhes in water, and thickening the ley by evaporation.

This liquor might be employed alſo to kill bugs and other domeſtic inſects; but on account of its ſtrong lixivious ſmell, M. Socoloff thinks it could not be uſed with ſafety in houſes that are inhabited. Nothing, however, more ſpeedily or more effectually deſtroys bugs, as our author ſays he has repeatedly experienced, than the oily pickle that remains in caſks in which ſalted herrings have been packed.

EASTANALLE, the north-eaſt head branch of Alabama river in Georgia, on which ſtands the town of Eaſtanallee.—*Morſe.*

EAST BETHLEHEM, a townſhip in Waſhington co. Pennſylvania.—*ib.*

EAST CHESTER, a townſhip in Weſt Cheſter co. New-York, on Long-Iſland ſound, about 8 miles S. W. of Rye, 5 northerly of Weſt Cheſter, and 17 N. E. of New-York. It contains 740 inhabitants ; of whom 106 are electors, and 75 ſlaves.—*ib.*

EASTER, an iſle in the Pacific ocean. S. lat. 27. 8. W. long. 109. 41. It is barren and has no freſh water.—*ib.*

EASTERN *Iſland* on the E. ſide of Cheſapeak bay, at the mouth of Cheſter river.—*ib.*

EASTERN-PRECINCT, in Somerſet co. New-Jerſey, contains 2068 inhabitants, of whom 468 are ſlaves.—*ib.*

EASTERN-RIVER, a ſettlement in Hancock co. diſtrict of Maine, containing 240 inhabitants.—*ib.*

EASTERTON, a village in Dauphin co. Pennſylvania, on the E. ſide of Suſquehanna river 4 miles N. by W. of Harriſburg, and 111 N. W. by W. of Philadelphia.—*ib.*

EAST GREENWICH, a poſt town, and the chief townſhip in Kent co. Rhode-Iſland ; 16 miles S. of Providence, and 22 N. N. W. of Newport, and contains 1824 inhabitants. The compact part called Greenwich town, has a number of dwelling-houſes, a meeting-houſe, and handſome court-houſe ; and although its commerce is greatly reduced, carries on the fiſheries to advantage, and ſends ſome veſſels to the Weſt-Indies. It is ſituated on the N. W. part of Narraganſet bay. Both this town and Warwick are noted for making good cider ; and formerly for raiſing tobacco for exportation.—*ib.*

EAST HADDAM, a townſhip in Middleſex co. Connecticut, ſituated on the E. ſide of Connecticut river, oppoſite to Haddam, of which it was formerly a part. It was ſettled in 1704, and lies 14 miles ſouthwardly of Middleton, and 21 N. W. of New-London.—*ib.*

EASTHAM, a townſhip in Barnſtable co. Maſſachuſetts, about 10 miles long, ſituated on the peninſula of Cape Cod, between Chatham and Wellfleet, and 95 or 100 miles S. E. of Boſton. It contains 1834 inhabitants.—*ib.*

EAST HAMPTON, a townſhip in Hampſhire co. Maſſachuſetts, 6 miles S. of Northampton, and 105 W. by S. of Boſton. It contains 457 inhabitants, and is divided from the W. bank of Connecticut river by the celebrated mountain called *Mount Tom.*—*ib.*

East Hampton, a handſome town in Suffolk co. New-York, on the S. E. coaſt of Long-Iſland, 12 miles E. N. E. of South Hampton, and 105 E. of New-York city. It has a Preſbyterian church, an academy, and about 80 dwelling-houſes in one ſtreet. The townſhip contains 1497 inhabitants, of whom 214 are electors. Gardner's Iſland is annexed to this town.—*ib.*

EAST HARTFORD, in Hartford co. Connecticut, lies on the E. bank of Connecticut river oppoſite to Hartford. The compact part of it lies in one broad ſtreet a mile and a half in length. Here are a number of mills on the different ſtreams which water the town ; alſo iron and glaſs works.—*ib.*

EAST HAVEN, a townſhip in New-Haven co. Connecticut, on the E. ſide of New-Haven harbour. There is a fort 2 miles from the mouth of the bay oppoſite Smith's point to defend the paſſage. The Scotch Captain and other ſmall iſlots and rocks lie on the S. ſhore.—*ib.*

East Haven, a townſhip in Eſſex co. Vermont, W. of Maidſtone, 11 miles S. E. of the ſouthern end of of Willoughby's lake, and 18 N. by W. of the upper bar of the 15 mile falls on Connecticut river.—*ib.*

EAST KINGSTON, in Rockingham co. New-Hampſhire, a part of Kingſton. In 1790 it contained 358 inhabitants; and now 906.—*ib.*

EAST MAIN, is that part of New-Britain, or Labrador, in North America, which lies on the E ſide of James's bay ; as part of New South Wales on the W. ſide of the ſame bay is called West-Main.

The Hudſon's bay factory called Eaſt Main, is ſituated on the S. part of Eaſt-Main, between Rupert and Slade rivers, both of which run weſtward into James's bay.—*ib.*

EASTON, a poſt town of Pennſylvania, and capital of Northampton co. ; pleaſantly ſituated at the mouth of the Lehigh ; and on the W. ſide of Delaware river. It is regularly laid out, and contains about 150 dwelling houſes, a church, court-houſe, regiſter's office, and an academy. It is 12 miles N. E. of Bethlehem, and 70 N. of Philadelphia.

Easton, the chief town of Talbot co. Maryland, formerly called Talbot Court-Houſe, is on the E. ſide of Cheſapeak bay, near the forks of Treadhaven river, 12 miles from its junction with Choptank river. It has a handſome court-houſe and market-houſe ; about 150 dwelling-houſes, and ſeveral ſtores for the ſupply of the adjacent country. It is 5 miles S. weſterly of Williamſburg, 37 S. of Cheſtertown, and 118 S. W. of Philadelphia.—*ib.*

Easton, a townſhip in Waſhington co. New-York. In 1790 it contained 2539 inhabitants, of whom 48 were ſlaves. By the ſtate cenſus of 1796, it appears that 347 of its preſent inhabitants are electors.—*ib.*

Easton, or *Eaſtown*, a townſhip important for its iron manufactures, ſituated in Briſtol co. Maſſachuſetts, near the head of Raynham river; 6 miles N. W. of Raynham, and 12 W. of Bridgewater. It contains 1466 inhabitants. The beſt mill-ſaws in the ſtate are made here. The art of making ſteel was introduced here by Capt. Eliphalet Leonard, in 1786. It is made in quantities; and is cheaper than imported ſteel, and equal in quality for large work, ſuch as plough ſhares, horſe-ſhoes, &c. which require large quantities of hard ſteel. But for edge tools, in general, it is found to be of inferior quality to what is imported. The manufacture of linſeed oil began here in 1792, and from an annual ſtock of 3000 buſhels of ſeed, there has been annually produced near 5000 gallons of oil.—*ib.*

EASTON's *Beach* and *Bay*, in the ſtate of Rhode-Iſland, is ſeparated from Sachueaſt beach and bay by Eaſton's point. Both lie at the ſouthern end of Rhode-Iſland.—*ib.*

EAST *River* in the ſtate of New-York, and the waters of North or Hudſon river, form York I. The communication between North river and Long-Iſland ſound is by the Eaſt river along the eaſtern ſide of New-York Iſland.—*ib.*

EAST or NORTH HAVEN, or *Quinepauge River* in Connecticut, riſes in Southington, not far from a bend in Farmington river and paſſing through Wallingford and North-Haven, empties into New-Haven harbour. It has been contemplated to connect the ſource of this river with Farmington river.—*ib.*

EAST-TOWN, in Cheſter co. Pennſylvania.—*ib.*

EAST-WHITELAND, a townſhip in Cheſter co. Pennſylvania.—*ib.*

EAST-WINDSOR, a townſhip in Hartford co. Connecticut: ſeparated from Windſor by Connecticut river, and about 7 miles N. E. of Hartford. The compact part of the town lies on one broad ſtreet of about 2 miles in length. In the townſhip are 3 Congregational churches. The lands are fertile; and beſides thoſe articles common to the ſtate, produce large quantities of good tobacco.—*ib.*

EATON, a ſmall town in the northern part of Strafford co. New-Hampſhire; 3 miles N. of the Great-Oſſipee lake, and about 56 N. by W. of Portſmouth. It was incorporated in 1766, and contains 253 inhabitants.—*ib.*

EATONTOWN, improperly called Edentown, a pleaſant village in New-Jerſey, about a mile S. of the town of Shrewſbury in the ſame townſhip. It is a place of ſome buſineſs and thriving.—*ib.*

EAU DE LUCE, a fragrant alkaline liquor which was ſome years ago in great repute, eſpecially among the fair ſex, and of which the leading perfection is, that it ſhall poſſeſs and retain a milky opacity.

Mr Nicholſon, in the ſecond number of his valuable journal, tells us, that being informed by a philoſophical friend, that the uſual recipes for making this compound (ſee CHEMISTRY, *Encycl.* n° 1037.) do not ſucceed, and that the uſe of maſtic in it has hitherto been kept a ſecret, he made the following trials to procure a good eau de luce.

One dram of the rectified oil of amber was diſſolved in four ounces of the ſtrongeſt ardent ſpirit of the ſhops; its ſpecific gravity being .840 at 60 degrees of Fahrenheit. A portion of the clear ſpirit was poured upon a larger quantity of fine powdered maſtic than it was judged could be taken up. This was occaſionally agitated without heat; by which means the gum reſin was for the moſt part gradually diſſolved. One part of the oily ſolution was poured into a phial, and to this was added one part of the ſolution of maſtic. No opacity or other change appeared. Four parts of ſtrong cauſtic volatile alkali were then poured in, and immediately ſhaken. The fluid was of a denſe opake white colour, affording a ſlight ruddy tinge when the light was ſeen through a thin portion of it. In a ſecond mixture, four parts of the alkali were added to one of the ſolution of maſtic; it appeared of a leſs denſe and more yellowiſh white than the former mixture. More of the gum reſinous ſolution was then poured in; but it ſtill appeared leſs opake than that mixture. It was ruddy by tranſmitted light. The laſt experiment was repeated with the oily ſolution inſtead of that of maſtic. The white was much leſs denſe than either of the foregoing compounds, and the requiſite opacity was not given by augmenting the doſe of the oily ſolution. No ruddineſs nor other remakable appearance was ſeen by tranſmitted light. Theſe mixtures were left at repoſe for two days; no ſeparation appeared in either of the compounds containing maſtic; the compound conſiſting of the oily ſolution and alkali became paler by the ſeparation of a cream at the top.

It appears, therefore, that the firſt of theſe three mixtures, ſubject to variation of the quantity of its ingredients, and the odorant additions which may be made, is a good eau de luce.

In a ſubſequent number of the ſame Journal, we have the following recipe by one of the author's correſpondents, who had often proved its value by experience. "Digeſt ten or twelve grains of the whiteſt pieces of maſtic, ſelected for this purpoſe and powdered, in two ounces of alcohol; and, when nearly diſſolved, add twenty grains of elemi (ſee AMYRIS, *Encycl.*). When both the reſins are diſſolved, add ten or fifteen drops of rectified oil of amber, and fifteen or twenty of eſſence of bergamot: ſhake the whole well together, and let the fæces ſubſide. The ſolution will be of a pale amber colour. It is to be added in very ſmall portions to the beſt aqua ammoniæ puræ, until it aſſumes a milky whiteneſs ſhaking the phial well after each addition, as directed by Macquer. The ſtrength and cauſticity of the ammoniac are of moſt eſſential conſequence. If, upon the addition of the firſt drop or two of the tincture, a denſe opake coagulated precipitate is formed, not much unlike that which appears on dropping a ſolution of ſilver into water ſlightly impregnated with common ſalt, it is too ſtrong, and muſt be diluted with alcohol. A conſiderable proportion of the tincture, perhaps one to four, ought to be requiſite to give the liquor the proper degree of opacity."

EAVES-BOARD, or EAVES-LATH, a thick feather-edged board, uſually nailed round the eaves of a houſe for the lowermoſt tiles, ſlate, or ſhingles, to reſt upon.

EBENEZER, a poſt town, and the capital of Effingham co. Georgia, ſeated on the S. W. bank of Savannah river, 5 miles from Abercorn, 25 N. N. W. of Savannah, 75 S. E. of Louiſville, and 860 S. W. of Philadelphia. It contains but a few houſes; and was ſettled in 1735, by a number of Proteſtants driven out of Saltſburg, in the electorate of Bavaria, by perſecution.—*Morse.*

ECLIPSAREON, an inſtrument invented by Mr Ferguſon for ſhewing the phenomena of eclipſes; as their time, quantity, duration, progreſs, &c.

ECLIPTIC. See *Encycl.* both under ECLIPTIC and in ASTRONOMY-*Index*. It was obſerved in ASTRONOMY, *Encycl.* n° 407. that the obliquity of the ecliptic has been found gradually to decreaſe. This was obſerved, among others, by *La Lande*, who, in the third edition of his aſtronomy, reckoned the ſecular diminution of this obliquity at 50 ſeconds. From a new examination, however, of ancient obſervations, he has ſince found reaſon to eſtimate it at only 36 ſeconds; but whether this be perfectly accurate, is very doubtful. The mean obliquity was determined for the 1ſt of January 1793, with circular inſtruments, by *Mechain* at Barcelona, and *Piazzi* at Palermo, to be 23° 27′ 53″.3. Yet the obſervation of the ſummer ſolſtice of 1796, by *Mechain* and *Le Francais*, gave 11 ſeconds more; which was juſtly conſidered as a perplexing circumſtance. But, as one of the ableſt of our literary journaliſts obſerves, might not this difference ariſe from the uncertainty of our tables of refraction, as affected by the hygroſcopic variations of the atmoſphere?

ECLIPTIC-Bounds, or *Limits*, are the greateſt diſtances from the nodes at which the ſun or moon can be eclipſed, namely, near 18 degrees for the ſun, and 12 degrees for the moon.

EDEN, a townſhip in Hancock co. diſtrict of Maine, incorporated in 1796, taken from the northerly part of Mount Deſert.—*Morſe.*

EDEN, a townſhip in Orleans co. Vermont, N. W. of Craftſbury, adjoining.—*ib.*

EDENTON, a diſtrict on the ſea-coaſt of North-Carolina, bounded N. by the ſtate of Virginia; E. by the ocean; W. by Halifax diſtrict, and S. by Newbern. It is ſubdivided into 9 counties, viz. Chowan, Paſquotank, Perquimins, Gates, Hertford, Bertie, and Tyrrel. It contains 53,770 inhabitants, of whom 19,198 are ſlaves. Its chief town is Edenton. The wood is chiefly pine, oak, cypreſs, and juniper; of all which there is abundance.—*ib.*

EDENTON, the capital of the above diſtrict, is a poſt town, and port of entry, at the head of a bay on the N. ſide of Albemarle ſound, and at the N. E. ſide of the opening of Chowan river. It contains above 150 indifferent wooden buildings, and a few handſome ones. The public buildings are an ancient brick Epiſcopal church, a court houſe and gaol. In or near the town lived the proprietary, and the firſt of the royal governors. Its ſituation is advantageous for trade, but unhealthy; which doubtleſs has tended to retard its proſperity. Its exports in the year ending September 30, 1794, amounted to the value of 50,646 dollars. It is 97 miles N. of Newbern, 257 N. N. E. of Wilmington, 139 S. E. of Peterſburgh, and 440 S. S. W. of Philadelphia. N. lat. 36. 6. W. long. 77. 11.—*ib.*

EDESTON, a plantation in Hancock co. diſtrict of Maine, containing 110 inhabitants.—*ib.*

EDGARTON, a port of entry and poſt town of Maſſachuſetts, and the chief town of Duke's co. ſituated on the E. ſide of the iſland of Martha's Vineyard. The fertile iſland of Chabaquidick is within the juriſdiction of Edgarton; which has a ſmall trade to the Weſt-Indies. The exports in 1794 for one year ending Sept. 30th, amounted to 2,257 dollars value. It lies about 14 miles S. of Barnſtable co. on the main, and 94 miles S. S. E. of Boſton. It was incorporated in 1671, and contains 1352 inhabitants.—*ib.*

EDGCOMB, a townſhip in Lincoln co. diſtrict of Maine, containing 855 inhabitants. It was incorporated in 1774, and lies 180 miles N. by E. of Boſton.—*ib.*

EDGCOMB, a county of Halifax diſtrict, N. Carolina, bounded S. by Pitt co. S. W. by Wayne co. and Tar river, which affords it communication with ſeveral counties in the ſtate; W. by Naſh co. and E. by Martin and Halifax counties. It contains 10,255 inhabitants, of whom 2,009 are ſlaves.—*ib.*

EDGEFIELD *Co.* in S. Carolina, is the ſouthernmoſt in the diſtrict of Ninety Six; bounded N. by Saluda river which divides it from Newbury co.; S. W. by Savannah river, which ſeparates it from the ſtate of Georgia; E. by Orangeburg diſtrict, and W. by Abbeville co. The ridge of elevated land, which divides the waters of Saluda from thoſe of Savannah river paſſes nearly through the middle of the county. Edgefield co. is about 34 miles long and 24 broad, and contains 13,289 inhabitants, of whom 3619 are ſlaves.—*ib.*

EDGEFIELD COURT-HOUSE, in the above county, where is a poſt-office, is 20 miles from Abbeville court-houſe; 25 from Auguſta, and 60 from Columbia.—*ib.*

EDGEMONT, a townſhip in Delaware co. Pennſylvania.—*ib.*

EDWARD, a fort in Nova-Scotia, in the town of Windſor, in Hants co. ſaid to be large enough to contain 200 men. It is ſituated on Avon river which is navigable thus far for veſſels of 400 tons; thoſe of 60 tons can go 2 miles higher.—*ib.*

EDWARD, a fortification in Waſhington co. New-York, now in ruins. It is ſituated on the E. bank of Hudſon river about 14 miles S. by E. of Fort George, on the ſouthern extremity of Lake George, and 19 S. by W. of Skeneſborough, on South bay, an arm of lake Champlain, N. lat. 43. 7. W. long. 74.—*ib.*

EDYSTONE Rocks, ſo remarkable for the light-houſe built on them, obtained their name from the great variety of contrary ſets of the tide or current in their vicinity. They are ſituated nearly S. S. W. from the middle of Plymouth Sound, according to the true meridian. The diſtance from the port of Plymouth is nearly 14 miles, and from the promontory called *Ram-head* about 10 miles. They are almoſt in the line, but ſomewhat within it, which joins the Start and the Lizard points; and as they lie nearly in the direction of veſſels coaſting up and down the channel, they were neceſſarily, before the eſtabliſhment of a light houſe, very dangerous, and often fatal to ſhips under ſuch circumſtances. Their ſituation, likewiſe, with regard to the Bay of Biſcay and Atlantic ocean, is ſuch, that they lie open to the ſwells of the Bay and ocean from all the ſouth-weſtern points of the compaſs: which ſwells are generally allowed by mariners to be very great and heavy in thoſe ſeas, and particularly in the Bay of Biſcay. It is to be obſerved, that the ſoundings of the ſea from the ſouth weſtward toward the Edyſtone are from 80 fathoms to 40, and everywhere till you come near the Edyſtone the ſea is full 30 fathoms in depth; ſo that all the heavy ſeas from the ſouth-weſt

Smeaton's Account of the Edyſtone Light-houſe.

of the truth of it: Mr Winſtanley being among his friends previous to his going off with his workmen on account of thoſe reparations, the danger being intimated to him, and that one day or other the light-houſe would certainly be overſet; he replied, "He was ſo very well aſſured of the ſtrength of his building, he ſhould only wiſh to be there in the greateſt ſtorm that ever blew under the face of the heavens, that he might ſee what effect it would have on the ſtructure."—It happened that Mr Winſtanley was but too amply gratified in this wiſh; for while he was there with his workmen and light-keepers, that dreadful ſtorm began, which raged moſt violently on the 26th of November 1703, in the night; and of all the accounts of the kind which hiſtory furniſhes us with, we have none that has exceeded this in Great Britain, or was more injurious or extenſive in its devaſtation. The next morning, November 27th, when the violence of the ſtorm was ſo much abated that it could be ſeen whether the light-houſe had ſuffered by it, nothing appeared ſtanding, but, upon a nearer inſpection, ſome of the large irons by which the work was fixed upon the rock; nor were any of the people, or any of the materials of the building, ever found afterwards, ſave only part of an iron chain, which had got ſo faſt jambed into a chink of the rock, that it could never afterwards be diſengaged till it was cut out in the year 1756."

Thus periſhed Mr Winſtanley, together with his building: but ſo great was the utility of that building while it ſtood, that the public could not fail to be deſirous of having another in its place. Accordingly, in 1706, an act of parliament of the 4th of Queen Anne was paſſed, for the better enabling the maſter, &c. of the Trinity-houſe of Deptford ſtrond to rebuild the ſame. By this act, the duties payable by ſhipping paſſing the light-houſe were veſted in the corporation of the Trinity-houſe, who were empowered to grant a leaſe to ſuch undertaker or undertakers as they ſhould approve. In conſequence, they agreed with a Captain *Lovel* or *Lovet* for a term of 99 years, commencing from the day on which a light ſhould be exhibited, and continuing ſo long as that exhibition ſhould laſt during the ſaid term. On this foundation Captain Lovet engaged Mr John Rudyerd to be his engineer or architect and ſurveyor.

It does not appear that Mr Rudyerd was bred to any mechanical buſineſs or ſcientific profeſſion, being at that time a ſilk mercer on Ludgate-hill; nor is it known that, in any other inſtance, he had diſtinguiſhed himſelf by any mechanical performance before or after. His want of perſonal experience, however, was in a degree aſſiſted by Mr Smith and Mr Norcutt, both ſhipwrights in the king's yard at Woolwich.

It is not, as Mr Smeaton obſerves, very material in what way this gentleman became qualified for the execution of his work; it is ſufficient that he directed the performance in a maſterly manner, and ſo as perfectly to anſwer the end for which it was intended. He ſaw the errors in the former building, and avoided them; inſtead of a polygon he choſe a circle for the outline of his building, and carried up the elevation in that form. His principal aim appears to have been *uſe* and *ſimplicity*; and indeed, in a building ſo ſituated, the former could hardly be acquired in its full extent without the latter. He ſeems to have adopted ideas the very reverſe of his predeceſſor; for all the unwieldy ornaments at top, the open gallery, the projecting cranes, and other contrivances, more for ornament and pleaſure than uſe, Mr Rudyerd laid totally aſide. He ſaw, that how beautiful ſoever ornaments might be in themſelves, yet when they are improperly applied and out of place, by affecting to ſhew a taſte, they betray ignorance of its firſt principle, *judgment*; for whatever deviates from propriety is erroneous, and at beſt inſipid.

It is impoſſible for us to give an accurate account of the conſtruction of Mr Rudyerd's light-houſe. We can only ſay, in general terms, that it was altogether built of wood; for the courſes of moorſtone, which Mr Rudyerd, adverting to the maxim, that *weight* is beſt reſiſted by *weight*, introduced into the ſolid part of his building, muſt be conſidered as being of the nature of ballaſt; the weight of theſe amounted to above 270 tons. The main column of the building conſiſted of one ſimple figure, being an elegant fruſtum of a cone, unbroken by any projecting ornament, or any thing on which the violence of the ſtorms could lay hold; meaſuring, excluſively of its ſloping foundation, 22 feet and eight inches on its largeſt circular baſe; 61 feet high above that circular baſe; and 14 feet and three inches in diameter at the top: ſo that the circular baſe was ſomewhat greater than one-third of the total height, and the diameter at the top was leſs than two-thirds of the baſe at the greateſt circle. On the flat roof of this main column, as a platform, Mr Rudyerd fixed his lantern, which was an octagon of ten feet and ſix inches diameter externally. The mean height of the window-frames of the lantern above the balcony floor was nearly nine feet; ſo that the elevation of the centre of the light above the higheſt ſide of the baſe was 70 feet; that is, lower than the centre of Mr Winſtanley's ſecond lantern by ſeven feet, but higher than that of his firſt by 24 feet. The width of Mr Rudyerd's lantern was, however, nearly the ſame as that of Mr Winſtanley's ſecond: but inſtead of the towering ornaments of iron-work, and a vane that roſe above the top of the cupola no leſs than 21 feet, Mr Rudyerd judiciouſly contented himſelf with finiſhing his building with a round ball of two feet and three inches diameter, which terminated at three feet above the top of his cupola. The whole height of Mr Rudyerd's light-houſe, from the loweſt ſide to the top of the ball, was 92 feet, on a baſe of 23 feet and four inches, taken at a medium between the higheſt and loweſt part of the rock that it covered. The whole building was completed in the year 1709, three years from its commencement.

This great work, after having braved the elements for forty-ſix years, was burnt to the ground in 1755. On the 2d of December of that year, when the light-keeper, then on the watch, went, about two o'clock in the morning, into the lantern, to ſnuff the candles according to cuſtom, he found it in a ſmoke; and in ſpite of all that he and his companions could do, the whole edifice was on fire in the compaſs of little more than eight hours, and in a few days was burnt to its foundation. The three light-men were with much difficulty got on ſhore, when one of them immediately ran off, and has never ſince been heard of. Another, who had been dreadfully burned by melted lead, of which, according to his own account, he had ſwallowed a quantity, lingered in agony for twelve days, and then expired. His ſtomach being opened, there was found in it a ſolid piece of lead of a flat oval form, which weighed ſeven ounces and five drachms; and thus was verified an aſſertion which, to the ſurgeon and others who attended him, appeared altogether incredible, *viz.* that any human being could live after receiving melted lead into the ſtomach.

On the deſtruction of Mr Rudyerd's light-houſe, Mr Smeaton (ſee Smeaton in this Supplement) was recommended by Lord Maccleſfield, then preſident of the Royal Society, as the fitteſt perſon in England to build another. It was with ſome difficulty that he was able to perſuade the proprietors that a ſtone building, properly conſtructed, would in all reſpects be preferable to one of wood; but having at laſt convinced them, he turned his thoughts to the ſhape which was moſt ſuitable to a building ſo critically ſituated. Reflecting on the ſtructure of the former buildings, it ſeemed a material improvement to procure, if poſſible, an enlargement of the baſe, without increaſing the ſize of the *waiſt*, or that part of the building which is between the top of the rock and the top of the ſolid work. Hence he thought a greater degree of ſtrength and ſtiffneſs would be gained, accompanied with leſs reſiſtance to the acting power. On this occaſion, the natural figure of the waiſt or bole of a large ſpreading oak occurred to Mr Smeaton.

"Let us (ſays he) conſider its particular figure.—Connected with its roots, which lie hid below ground, it riſes from the ſurface with a large ſwelling baſe, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter leſs by at leaſt one third, and ſometimes to half its original baſe. From thence, its taper diminiſhing more ſlowly, its ſides by degrees come into a perpendicular, and for ſome height form a cylinder. After that, a preparation of more circumference becomes neceſſary, for the ſtrong inſertion and eſtabliſhment of the principal boughs, which produces a ſwelling of its diameter.—Now we can hardly doubt but that every ſection of the tree is nearly of an equal ſtrength in proportion to what it has to reſiſt; and were we to lop off its principal boughs, and expoſe it in that ſtate to a rapid current of water, we ſhould find it as capable of reſiſting the action of the heavier fluid, when diveſted of the greater part of its clothing, as it was that of the lighter, when all its ſpreading ornaments were expoſed to the fury of the wind: and hence we may derive an idea of what the proper ſhape of a column of the greateſt ſtability ought to be, to reſiſt the action of external violence, when the quantity of matter is given of which it is to be compoſed."

The next thing to be conſidered was, how the blocks of ſtone could be bonded to the rock, and to one another, in ſo firm a manner as that not only the whole together, but every individual piece, when connected with what preceded, ſhould be proof againſt the greateſt violence of the ſea. For this purpoſe, cramping was the firſt idea, but was rejected on account of the great quantity of iron which was neceſſary, and from the trouble and loſs of time which would attend that operation. In its place was ſubſtituted the method of dovetailing. From ſome ſpecimens which Mr Smeaton had ſeen in Belidor's deſcription of the ſtone floor of the great ſluice at Cherburgh, (where the tails of the upright headers are cut into dovetails for their inſertion into the maſs of rough maſonry below,) he was led to think, that if the blocks themſelves were, both inſide and outſide, formed into large dovetails, they might be managed ſo as to lock one another together, being primarily engrafted into the rock; and in the round or entire courſes above the top of the rock, they might all proceed from, and be locked to, one large centre ſtone. Theſe particulars being digeſted in his own mind, he explained his deſign by the help of drawings: with which, after mature deliberation, the proprietors were perfectly ſatisfied; and declared, that the ſcheme was not only in itſelf practicable, but, as appeared to them, the only means of doing the buſineſs effectually.

During this time Mr Smeaton had never viſited the rock on which he was to be employed: he therefore reſolved to go to Plymouth early in the ſpring of 1756, that he might loſe no opportunity of viewing it. At Plymouth he met Mr Joſias Jeſſop, to whom he was referred for information and aſſiſtance, and who afterwards proved of great ſervice: he was not only an approved workman in his branch as a ſhipwright, but a competent draughtſman and an excellent modeller; 'in which laſt (ſays the author) he was accurate to a great degree: he therefore appeared to be a very fit perſon to overlook the exact execution of a deſign given.' Mr Jeſſop, like others, expreſſed his doubts that a ſtone building could ſtand on the Edyſtone: but they were removed by the propoſed mode of its conſtruction.—As Mr Smeaton was impatient to go to the rock, he ſeized the firſt opportunity that ſeemed to promiſe any chance of landing on it. On the 2d of April he got within a ſtone's throw of it, but could not land: on the 5th he was more fortunate; he now landed, and ſtaid on the rock for two hours and a half. This time was employed in taking a general view of the whole. No remains of the houſe could be perceived either on the rock, or about it, except the greateſt part of the iron branches that had been fixed by Mr Rudyerd; and ſome of the moorſtones were diſcerned lying in the bottom of the gut. Such traces were alſo obſerved of the ſituation of the irons fixed by Mr Winſtanley, as to render it no very difficult taſk to make out his plan, and the poſition of the edifice; whence it appeared very probable, that Mr Winſtanley's building was overſet altogether, and that it had torn up a portion of the rock itſelf, as far as the irons had been faſtened in it. With regard to the ſteps, which were ſaid to have been cut in the rock by Mr Rudyerd, the traces of only five were remaining; theſe were faintly cut, and without much regularity. It was next tried in what degree the rock was workable; and Mr Smeaton had the ſatisfaction of finding every thing ſucceed to his wiſhes.

Having thus determined that there was no impracticability in fixing a ſtone building, it became of the greateſt importance to ſecure a more ſafe and certain landing on the rock; as it would frequently happen, while the veſſels were lying off the rock, waiting for a favourable time to enter the gut, that tides might change, ground ſwells come on, winds ſhift, and ſtorms ariſe, which would of courſe make it deſirable to return to Plymouth, if poſſible, though the purpoſe of the voyage was unperformed. In addition to this,

when

The winter therefore of 1756, and the following ſpring, were employed in preparing materials for the outwork: the maſonry particularly required great attention. It was a deſirable object to uſe large and heavy pieces of ſtone in the building; yet their ſize muſt neceſſarily be limited by the practicability of landing them with ſafety. Now ſmall veſſels only could deliver their cargoes alongſide of this hazardous rock; and theſe could not deliver very large ſtones, becauſe the ſudden riſing and falling of the veſſels in the gut amounted frequently to the difference of three or four feet, even in moderate weather; ſo that in caſe after a ſtone was raiſed from the floor of the veſſel, her gunwale ſhould take a ſwing, ſo as to hitch under the ſtone, one of a very large magnitude muſt, on the veſſel's riſing, infallibly ſink her. From this conſideration, it was determined that ſuch ſtones ſhould be uſed as did not much exceed a ton weight; though occaſionally particular pieces might amount to two tons. That they might attain a certainty in putting the work together on the rock, the ſtones of each courſe were tried together in their real ſituation with reſpect to each other; and they were ſo exactly marked, that every ſtone, after the courſe was taken aſunder, could be replaced in the identical poſition in which it lay on the platform, within the fortieth part of an inch:—nor was this judged ſufficient; for every courſe was not only tried ſingly together on the platform and marked, but the courſe above it was put on it, and marked in the ſame way; ſo that every two contiguous courſes might fit each other on the outſide, and prevent an irregularity in the outline. This degree of accuracy might ſeem ſuperfluous: but as the nature of the building required the workmen to be in a condition to reſiſt a ſtorm at every ſtep, it became neceſſary to fix the centre ſtone firſt, as being leaſt expoſed to the ſtroke of the ſea; and in order to have ſure means of attaching all the reſt to this, and to one another, it was indiſpenſable that the whole of the two courſes ſhould be tried together; in order that, if any defect appeared at the outſide, by an accumulation of errors from the centre, it might be rectified on the platform.

Another circumſtance, to which Mr Smeaton was particularly attentive, and concerning which his remarks are very valuable, was to aſcertain the moſt proper compoſition for water cements. In making mortar for buildings expoſed to water, *tarras* had been moſt eſteemed: but ſtill there were objections to its uſe. Mr Smeaton was therefore induced to try the *terra puzzolana*, found in Italy, as a ſubſtitute for *tarras*. Fortunately there was a quantity of it in the hands of a merchant at Plymouth, which had been imported as a venture from Civita Vecchia when Weſtminſter-bridge was building; and which he expected to have ſold for that work to a good advantage, but failed in his ſpeculation; for having found that *tarras* anſwered their purpoſe, neither commiſſioners, engineers, nor contractors, would trouble themſelves to make a trial of the other material. This was found in every reſpect equal to *tarras*, as far as concerned the hardening of water-mortar, if not preferable to it; and if made into a mortar with lime produced from a ſtone found at Aberthaw, on the coaſt of Glamorganſhire, it exceeded, in hardneſs, any of the compoſitions commonly uſed in dry work; and in wet and dry, or wholly wet, was far ſuperior to any which Mr Smeaton had ſeen, inſomuch, that he did not doubt its making a cement that would equal the beſt merchantable Portland ſtone in ſolidity and durability.

Theſe preliminary arrangements being ſettled, they proceeded, on the 3d of June 1757, to carry out the Neptune buſs, and to begin the work. After getting up the moorings (a work of no ſmall difficulty and ſome danger), and after fixing the fender piles, the ſhears, windlaſs, &c. the firſt ſtone was landed, got to its place, and fixed, on Sunday the 12th of June; and on the next day the firſt courſe was completed. On the 14th, the ſecond courſe was begun: but, in conſequence of a freſh gale, the workmen were obliged to quit the rock, after ſecuring every thing as well as poſſible. Such was the violence of the gale, that it was impracticable for the boats to get out of the gut, otherwiſe than by paſſing the Sugar loaf rock, in which they providentially ſucceeded. On the 18th, they were again as ſuddenly driven from their work, and ſeveral pieces of ſtone were waſhed away by the violence of the ſea. In the night of the 6th of July, the watch on the deck of the buſs eſpied a ſail on the rocks, and one of the yawls was ſent to her relief, which brought back the whole crew, ſeveral of whom were in their ſhirts, and in great diſtreſs. It was a ſnow of about 130 tons burthen, which was returning in ballaſt from Dartmouth; but not knowing exactly where they were, they had miſtaken the rocks for ſo many fiſhing boats, till it was too late to clear them; and on the veſſel's ſtriking, ſhe filled ſo quickly, that the boat floated on deck before they could get into it.

During this time, the building went on, though its progreſs was retarded by various interruptions and accidents; till, at the latter end of Auguſt, when the ſeventh courſe was nearly finiſhed, a violent ſtorm aroſe, which carried away the ſhears and triangles, together with two of the largeſt ſtones which had been left chained on the rock! yet notwithſtanding theſe and various other difficulties, the ninth courſe was completed by the end of September.

"Being now arrived at the eve of October (ſays Mr Smeaton), I maturely conſidered our ſituation; and finding that we had been 18 days in completing the laſt courſe, whereas the former one was begun and finiſhed in five, though the weather, both on ſhore and above head, had remained to all appearance much the ſame; I from thence concluded it to be very probable, we might not get another courſe completed in the compaſs of the month of October: So that when I reflected on the many diſaſters that we had ſuffered laſt year by continuing out to the month of November, and how little work we in reality did after this time, it appeared to me very problematical whether we might be able, with every poſſible exertion, to get another courſe finiſhed this ſeaſon; and conſidering how very ineligible it was to have a courſe lie open during the winter in this ſtage of the work, and that we had now got three complete courſes eſtabliſhed above the top of the rock, the ſum of whoſe height was four feet ſix inches; and that we could not leave the work in a more defenſible ſtate, whether as relative to the natural violence of the ſea, or the poſſibility of external injuries—from theſe conſiderations, it appeared to me highly proper to put a period to the outwork of the preſent ſeaſon."

At the commencement of the following year, 1758, the weather proved very tempeſtuous till March ; and on viſiting the rock, they diſcovered that the great buoy on the moorings had been carried away; nor were the mooring chains, though ſought with the greateſt perſeverance, recovered till the middle of May. In conſequence of this delay, and from other accidents, the tenth courſe of the building was not completed till the 5th of July. From this time the progreſs was without any very material interruption; ſo that on the 26th of September the 25th courſe, being the firſt of the ſuperſtructure, was finiſhed. The work was now ſo far advanced, that Mr Smeaton made a propoſal to the Trinity Board and to the proprietors of exhibiting a light during the enſuing winter; and for this purpoſe he continued his operations longer than he otherwiſe would have done, in order to complete the firſt room, and make it habitable; but foul weather coming on, he was obliged to quit the rock, and returned to Plymouth. A ſtorm enſued; and, on the next morning, looking out with his teleſcope, he could diſcern the houſe with the ſea breaking over it, but nothing of the buſs. On the following day, the air being more clear, he had a diſtinct view of the building; but the buſs was really gone. This was a day of double regret, as it likewiſe brought a negative on his propoſal for exhibiting a light from the houſe during the winter. The buſs had run into Dartmouth harbour; ſhe was brought home; and the work on the rock being ſecured againſt the winter, the operations of the third ſeaſon were cloſed.

During the early part of 1759, Mr Smeaton was employed in London in forming and making out the neceſſary deſigns for the iron rails of the balcony, the caſt iron, the wrought iron, and the copper works for the lantern, together with the plate glaſs work. It was not till the 22d of June that he arrived at Plymouth. As the moorings had been again loſt, new chains were provided, and the buſs was once more fixed in her ſituation. On the 5th of July he landed on the rock, and found every thing perfectly ſound and firm, without the leaſt perceptible alteration, excepting that the cement, uſed in the firſt year, now in appearance approached the hardneſs of the moor-ſtone; and that uſed in the laſt year had the full hardneſs of Portland; but on hauling up the ſtones for the next circle from the ſtore-room, where they had been depoſited, he had the mortification to find only ſeven inſtead of eight. It was imagined that a body of falling water, making its way through the open ribs of the centre, had waſhed this ſtone out of the ſtore-room door, though it weighed between four and five hundred weight.

The progreſs of the work, however, was now ſuch, that a whole room, with its vaulted cover, was built complete in ſeven days.

On the 17th of Auguſt the main column was completed.

On the 27th Mr Richardſon and his company left the Edyſtone, and gave an account that they had lived in it ſince the 23d, having found it much more warm than the buſs's hold and cabin.

They had now finiſhed every thing belonging to the maſonry. The work of the cupola was going on briſkly in the yard at Mill-bay, though it was retarded by the ſucceſſive illneſſes of the two principal copperſmiths. However, by the exertions of Mr Smeaton, who was himſelf ready to work at every buſineſs, all matters were put in ſuch forwardneſs, that by the 8th of September there was nothing to prevent the frame of the lantern from being fixed in its place but bad weather. It was not till the 15th that the weather permitted the boats to deliver their cargoes. The 16th was remarkably fine; ſo that by the evening the whole frame of the lantern was ſcrewed together, and fixed in its place. On the 17th, which was alſo exceedingly fine, the cupola was brought out, and the ſhears and tackle were ſet up for hoiſting it.

"This (ſays Mr Smeaton) perhaps may be accounted one of the moſt difficult and hazardous operations of the whole undertaking; not ſo much on account of its weight, being only about 11 cwt. as on account of the great height to which it was to be hoiſted clear of the building, and ſo as, if poſſible, to avoid ſuch blows as might bruiſe it. It was alſo required to be hoiſted a conſiderable height above the balcony floor; which, though the largeſt baſe that we had for the ſhears to ſtand on, was yet but 14 feet within the rails, and therefore narrow in proportion to their height. About noon the whole of our tackle was in readineſs; and in the afternoon the Weſton (boat) was brought into the gut, and in leſs than half an hour her troubleſome cargo was placed on the top of the lantern without the leaſt damage. During the whole of this operation it pleaſed God that not a breath of wind diſcompoſed the ſurface of the water, and there was the leaſt ſwell about the rocks I had obſerved during the ſeaſon.

"Tueſday, September 18th, in the morning, I had the ſatisfaction to perceive the Edyſtone boat, on board of which I expected the ball to be; and which being double gilt, I had ordered the carriage of it to be carefully attended to. The wind and tide were both unfavourable to the veſſel's getting ſoon near us; therefore, being deſirous to get the ball ſcrewed on before the ſhears and tackle were taken down, one of the yawls was diſpatched to bring it away. This being done, and the ball fixed, the ſhears and tackle were taken down, which took up nearly as much time as was employed in ſetting them up; that is, near 12 hours each, in the whole, to do the work of an hour.—I muſt obſerve, that by choice I ſcrewed on the ball with mine own hands, that in caſe any of the ſcrews had not held quite tight and firm, the circumſtance might not have been ſlipped over without my knowledge; being well aware, that even this part would at times come to a conſiderable ſtreſs of wind and ſea, and which could not be replaced without ſome difficulty in caſe any thing ſhould fail.—It may not be amiſs to intimate to thoſe who may in future have to perform the ſame operation, that the ſcaffold on which this was done conſiſted of four boards only, well nailed together, at ſuch diſtances as to permit it to be lifted over the ball when done with. It reſted on the cupola, encompaſſing its neck; and Roger Cornthwaite, one of the maſons, placed himſelf on the oppoſite ſide upon it, to balance me while I moved round to fix the ſcrews."

Reſpecting the diſpoſition of the internal part of the edifice, Mr Smeaton fixed the beds in the uppermoſt room, and the fire-place, which conſtituted the kitchen, in the room below it; whereas, in the late houſe, the upper room was the kitchen, and the beds were placed from, or founded upon, ſome general propoſitions, are called the *geometrical effection* of them.

EFFINGHAM, formerly Leavitſtown, a townſhip in Strafford co. New-Hampſhire, S. E. of Oſſipee pond, on Oſſipee river, incorporated in 1766, and has 154 inhabitants.—*Morse.*

Effingham *Co.* in the lower diſtrict of Georgia, is bounded by Savannah river on the N. eaſtward, which ſeparates it from S. Carolina; by Ogeechee river on the S. weſtward, which divides it from Liberty co. It contains 2424 inhabitants, including 750 ſlaves. Chief towns, Ebenezer and Elberton.—*ib.*

EGG-HARBOUR, a town in Glouceſter co. New-Jerſey, on Great Egg Harbour: famous for the exportation of pine and cedar.—*ib.*

Egg Harbour R. Great and Little. Great Egg Harbour river riſes between Glouceſter and Cumberland counties, in New-Jerſey. After running E. S. E. a few miles it becomes the diviſional line between Cape May and Glouceſter counties, and falls into the bay of its own name. The inlet from the Atlantic ocean lies in 39. 22. The river abounds with ſheepſhead, rock-fiſh, perch, oyſters, clams, &c. which find a ready market at Philadelphia. This river is navigable 20 miles for veſſels of 200 tons.—*ib.*

Little Egg Harbour Inlet, lies about 17 miles N. E. of Great Egg Harbour Inlet. It receives Mulicus river which riſes in Glouceſter and Burlington counties, and forms part of the diviſional line a few miles from the bay. It is navigable 20 miles for veſſels of 60 tons. The townſhip of *Little Egg Harbour*, in Burlington co. conſiſts of about 23,000 acres; the moſt of which being thin and barren, is not under improvement. The compact part of the townſhip is called *Clam Town*, where there is a meeting-houſe for Friends, and about a dozen houſes. It has a ſmall trade to the Weſt-Indies. During the late war captains Ferguſon and Collins burnt a number of privateers and other veſſels in Little Egg Harbour, and deſtroyed the place.—*ib.*

Egg *Iſland*, a ſmall iſland on the N. E. ſide of Delaware bay, in Cumberland co.—*ib.*

EGLANTINE (Fabre de), was born at Chalons in Champagne. He was early educated, by the care of his parents, in polite literature and natural philoſophy. From his youth he felt an invincible inclination to court the muſes; and in the year 1786 he publiſhed, in a French periodical work, intitled *Les Etrennes du Parnaſſe*, a little poem called *Chalons ſur Marne*, in which he drew a very charming picture of the moral pleaſures that were to be found in that place and its neighbourhood. This piece, however, was then conſidered as a juvenile compoſition, and fell very ſhort of that high degree of celebrity which the author afterwards attained to. In the years 1789 and 1790 he publiſhed two well-known comedies, *Le Philinte*, and *L'Intrigue Epiſtolaire*. Beſides his talents for writing comedies, he felt, like Moliere, an inclination to perform parts on the ſtage. He accordingly acted his own plays in the theatres of Lyons and Nimes.

Being, like the greater part of French wits and philoſophers, an avowed enemy to religion and civil ſubordination, he was thought to have ſufficient merit to be removed from the office of fabricating comedies to that of fabricating conſtitutions. Accordingly, in 1792, he was choſen (we believe by the influence of the Girondine faction) a deputy to the National Convention. In that aſſembly, during the winter and the ſpring of 1793, he acted a part certainly not very commendable, though every way worthy of the pupil of the economiſts. At that period the Girondine party was the moſt powerful; and it was very generally reported among the beſt informed people at Paris, that Fabre contributed, together with Danton and Robeſpierre, to the famous maſſacre of the 31ſt of May, when the Girondine faction was overthrown by a popular inſurrection. What gives the appearance of authenticity to this report is, that Fabre himſelf ſome days afterwards obſerved to a friend, that the domineering ſpirit of the Girondines, who had engroſſed all power and office, had induced him and his colleagues, in order to ſhake off the yoke, to throw themſelves into the hands of the *Sanſculoterie*; that he could not help, however, foreboding dangerous conſequences from that day, 31ſt of May, as the ſame mob which they had taught to deſpiſe the legiſlature might, at the inſtigation of another faction, overthrow him in his turn. Thus Fabre appeared to have a preſentiment of his own future deſtiny.

On the overthrow of the Girondine party, and the eſtabliſhment in power of the Sanſculoterie, Fabre began to act a conſiderable part. He was appointed member of the Committee of Public Inſtruction; in which ſtation, in the month of Auguſt 1793, he gave his vote for ſuppreſſing all academies and literary corporations which, from their privileges and ariſtocratic ſpirit, were conſidered as unfriendly to a truly republican government. In October 1793, he ſubmitted to the National Convention the plan of a new calendar, which was afterwards adopted.

The reader who will take the trouble to turn to the article Revolution, n° 184, *Encycl.* may ſee that calendar, and be able to judge for himſelf whether it evinces the childiſhneſs or the ſcience of its author. A journaliſt of our own indeed, who ſeems to admire every thing that is new and odd, ſays, that the accuracy and regularity with which it was executed, evinced an *uncommon* degree of knowledge in mathematics and natural philoſophy, and failed not to reflect on its author great reputation! Indeed! Had the Sanſculotes ſo ſoon forgotten their "guides, philoſophers, and friends," D'Alembert, and Condorcet, as to conſider this exploit as ſufficient to place its author in the temple of fame among the ſons of ſcience? Our journaliſt, however, admits, that it gave birth to a pleaſant pamphlet, intitled *Le Légiſlateur à la Mode*; in which it was demonſtrated, that the 31ſt chapter of the travels of Anacharſis, by the Abbe Barthelemy, where the deſcription of the ancient Greek calendar is introduced, had furniſhed no inconſiderable part of the plan of the new Fabrine calendar.

The Sanculoterie had now become too powerful to be tolerated any longer. In the winter of 1794, that faction was divided into two parts, the *Jacobins* and the *Cordeliers*, or, in other words, the *Robeſpierriſts* and the *Dantoniſts*. Fabre was of the faction of Danton, and was confined with Danton's adherents in the priſon of the Luxemburg. From that priſon he wrote a number of letters, which were afterwards printed. Theſe letters are highly extolled as beautiful deſcriptions of ſenſibility and talents in diſtreſs. After a month's impriſonment, Fabre was, with many others, executed in the *place de la Revolution*, in April 1794, in the 35th year of his age. His ſentence, we believe, was unjuſt; but death he had more than merited.

EGMONT, an iſland in the South Pacific ocean, diſcovered by capt. Carteret. The Spaniards called it Santa Cruz. S. lat. 19. 20. E. long. from Greenwich 164. 30.—*Morſe*.

EGREMONT, a townſhip in Berkſhire co. Maſſachuſetts, containing 759 inhabitants, incorporated in 1760—15 miles S. W. of Stockbridge, and 145 W. of Boſton.—*ib.*

EIGHTEEN-MILE, or *Long Beach*, on the coaſt of New-Jerſey, lies between Little Egg Harbour inlet, and that of Barnegat.—*ib.*

ELASTICITY. In addition to the article in the *Encyclopædia*, ſee, in this *Supplement*, the view of BOSCOVICH's theory of natural philoſophy, n° 26.

ELBERT, a new county in the upper diſtrict of Georgia, on the tract of land between Tugulo and Broad rivers. The S. E. corner of the county is at their confluence, at the town of Peterſburg. On the N. W. it is bounded by Franklin county.—*Morſe*.

ELBERTON, the ſeat of juſtice in the above co. is 23 miles N. W. of Peterſburg, and 30 S. E. of Franklin court-houſe.—*ib.*

ELBERTON, a poſt town in Effingham co. Georgia, on the N. E. bank of Ogeechee river, containing about 30 houſes. It is about 19 miles W. of Ebenezer, 48 N. W. of Savannah, and 55 S. E. of Louiſville. N. lat. 32. 18. 45. W. long. 80. 30.—*ib.*

ELECTIONS, or CHOICE, ſignify the ſeveral different ways of taking any number of things propoſed, either ſeparately, or as combined in pairs, in threes, in fours, &c.; not as to the order, but only as to the number and variety of them. Thus, of the things a, b, c, d, e, &c. the elections of
one thing are $(a)\ 1 = 2^1 - 1$,
two things are $(a, b, ab,)\ 3 = 2^2 - 1$,
three things are $(a, b, c, ab, ac, bc, abc,)\ 7 = 2^3 - 1$,
&c.; and of any number n, all the elections are $2^n - 1$; that is, one leſs than the power of 2 whoſe exponent is n, the number of ſingle things to be choſen, either ſeparately or in combination.

ELECTRICITY.

WE cannot but be ſomewhat ſurpriſed that, among the many attempts which have been made by the philoſophers of Britain to explain the wonderful phenomena which are claſſed under this name, no author of eminence, beſides the Hon. Mr Cavendiſh and Lord Mahon, have availed themſelves of their ſuſceptibility of mathematical diſcuſſion; and our wonder is the greater, becauſe it was by a mathematical view of the ſubject, in the phenomena of attraction and repulſion, that the celebrated philoſopher Franklin was led to the only knowledge of electricity that deſerves the name of ſcience; for we had ſcarcely any leading facts, by which we could claſs the phenomena, till he publiſhed his theory of *poſitive* and *negative*, or *plus* and *minus* electricity. This is founded entirely on the phenomena of attraction and repulſion. Theſe furniſh us with all the indications of the preſence of the mighty agent, and the marks of its kind, and the meaſures of its force. Mechanical force accompanies every other appearance; and this accompanyment is regulated in a determinate manner. Many of the effects of electricity are ſtrictly mechanical, producing local motion in the ſame manner as magnetiſm or gravitation produce it. One ſhould have expected that the countrymen of Newton, prompted by his ſucceſs and his fame, would take to this mode of examination, and would have endeavoured to deduce, from the laws obſerved in the action of this motive force, an explanation of other wonderful phenomena, which are inſeparably connected with thoſe of attraction and repulſion.

But this has not been the caſe, if we except the labours of the two philoſophers above mentioned, and a few very obvious poſitions which muſt occur to all the inventors and improvers of electrometers, batteries, and other things of meaſurable nature.

This view has, however, been taken of the ſubject by a philoſopher of unqueſtioned merit, Mr Æpinus of the Imperial Academy of St Peterſburgh. This gentleman, ſtruck with the reſemblance of the electrical properties of the tourmalin to the properties of a magnet, which have always been conſidered as the ſubject of mathematical diſcuſſion, fortunately remarked a wonderful ſimilarity in the whole ſeries of electrical and magnetical attractions and repulſions, and ſet himſelf ſeriouſly to the claſſification of them. Having done this with great ſucceſs, and having maturely reflected on Dr Franklin's happy thought of plus and minus electricity, and his conſequent theory of the Leyden phial, he at laſt hit on a mode of conceiving the whole ſubject of magnetiſm and electricity, that bids fair for leading us to a full explanation of all the phenomena; in as far, at leaſt, as it enables us to claſs them with preciſion, and to predict what will be the reſult of any propoſed treatment. He candidly gives it the modeſt name of a hypotheſis.

This was publiſhed at St Peterſburg in 1759, under the title of *Theoria Electritatis et Magnetiſmi*, and is unqueſtionably one of the moſt ingenious and brilliant performances of this century. It is indeed moſt ſurpriſing that it is ſo little known in this country. This, we imagine, has been chiefly owing to the very ſlight and almoſt unintelligible account which Dr Prieſtley has given of it in his hiſtory of electricity; a work which profeſſes to comprehend every thing that has been done by the philoſophers of Europe and America for the advancement of this part of natural ſcience, and which indeed contains a great deal of inſtructive information, and, at the ſame time, ſo many looſe conjectures and inſignificant obſervations, that the reader (eſpecially if acquainted with the Doctor's character as an unwearied bookmaker) reaſonably believes that he has let nothing ſlip that was worthy of notice. We do not pretend to account for the manner in which Dr Prieſtley has mentioned this work, ſo much, and ſo deſervedly celebrated on the continent. We cannot think that he has read it ſo as to comprehend it, and imagine, that ſeeing ſo much algebraic notation in every page, and being at that time a novice in mathematical learning, he contented himſelf with a few ſcattered paragraphs which were free of thoſe embarraſſments; and thus could only get a very imperfect notion of the ſyſtem. The Hon. Mr Cavendiſh has done it more juſtice in the 61ſt volume of the Philoſophical Tranſactions, and conſiders his own moſt excellent diſſertation only as an extenſion and more accurate application of Æpinus's Theory. That we have not an account of this expoſition of the Franklinian theory of electricity in our language, is a material want in Britiſh literature; and we truſt, therefore, that our readers will be highly pleaſed with having the ingenious diſcoveries of the great American philoſopher put into a form ſo nearly approaching to a ſyſtem of demonſtrative ſcience.

We propoſe, therefore, in this place, to give ſuch a brief account of Æpinus's theory of electricity, as will enable the reader to reduce to a very ſimple and eaſily remembered law all the phenomena of electricity which have any cloſe dependence on the mechanical effects of this powerful agent of nature; referring for a demonſtration of what is purely mathematical to Sir Iſaac Newton's Principia, and the Diſſertation by Mr Cavendiſh already mentioned, except in ſuch important articles as we think ourſelves able to preſent in a new, and, we hope, a more familiar form. We do not mean, in this place, to give a ſyſtem of philoſophical electricity, nor even to narrate and explain the more remarkable phenomena. Of theſe we have already given a vaſt collection in the article ELECTRICITY, *Encycl.* We confine ourſelves to the phenomena which may be called *mechanical*, producing meaſurable motion as their *immediate* effect; and thus giving us a principle for the mathematical examination of the cauſe of electrical phenomena. We ſhall conſider the reader as acquainted with the other phyſical effects of electricity, and ſhall frequently refer to them for proofs.

Moreover, as our intention is merely to give a ſynoptical view of this elaborate and copious performance of Mr Æpinus, hoping that it will excite our countrymen to a careful peruſal of ſo valuable a work, we ſhall omit moſt of the algebraic inveſtigations contained in it, and preſent the concluſions in a more familiar, and not leſs convincing, form. At the ſame time we will inſert the valuable additions made by Mr Cavendiſh, and many important particulars not noticed by either of thoſe gentlemen.

HYPOTHESIS OF ÆPINUS.

1 Hypotheſis THE phenomena of electricity are produced by a fluid of peculiar nature, and therefore called the ELECTRIC FLUID, having the following properties:

2 1. Its particles repel each other, with a force decreaſing as the diſtances increaſe.

3 2. Its particles attract the particles of ſome ingredient in all other bodies, with a force decreaſing, according to the ſame law, with an increaſe of diſtance; and this attraction is mutual.

4 3. The electric fluid is diſperſed in the pores of other bodies, and moves with various degrees of facility through the pores of different kinds of matter. In thoſe bodies which we call *non-electrics*, ſuch as water or metals, it moves without any perceivable obſtruction; but in glaſs, roſins, and all bodies called *electrics*, it moves with very great difficulty, or is altogether immoveable.

5 4. The phenomena of electricity are of two kinds; 1. Such as ariſe from the actual motion of the fluid from a body containing more into one containing leſs of it. 2. Such as do not immediately ariſe from this transference, but are inſtances of its attraction and repulſion.

Theſe things being ſuppoſed, certain conſequences neceſſarily reſult from them, which ought to be analogous to the obſerved phenomena of electricity, if this hypotheſis be complete, or ſome farther modification of the aſſumed properties is neceſſary, in order to make the analogy perfect.

6 Plate XXIV. Suppoſe the body A (fig. 1.) to contain a certain quantity of fluid. Its particles adjoining to the ſurface, ſuch as P, are attracted by the particles of common matter in the body, but repelled by the other particles of the fluid. The totality of the attractive forces acting on P may be equal to the totality of the repulſive forces, or may be unequal. If theſe two ſums are equal, P is in equilibrio, and has no tendency to change its place. But there may be ſuch a quantity of fluid in the body, that the repulſions of the fluid exceed the attractions of the common matter. In this caſe, P has a tendency to quit the body, or there is an expulſive force acting on it, and it *will* quit the body if it be moveable. Becauſe the ſame muſt be admitted in reſpect of every other particle of moveable fluid, it is plain that there will be an efflux, till the attraction of the common matter for the particles of fluid is equal to the repulſion of the remaining fluid. On the other hand, if the primitive repulſion of the fluid acting on the particle P be leſs than the attractions of the common matter, there will be the ſame, or at leaſt a ſimilar, ſuperiority of attraction acting on the fluid reſiding in the circumambient bodies; and there will be an influx from all hands, till an equilibrium be reſtored.

7 Natural quantity, why ſo called. Hence it follows, that there may always be aſſigned to any body ſuch a quantity of fluid that there ſhall be no tendency either to efflux or influx. But if the quantity be increaſed, and nothing prevent the motion, the redundant fluid will flow out; and if the proper quantity be diminiſhed, there will be an influx of the ſurrounding fluid, if not prevented by ſome external force. This may be called the body's NATURAL QUANTITY; becauſe the body, when left to itſelf, will always be reduced to this ſtate.

8 If two bodies, A and B, contain each its natural quantity, they will not exert any ſenſible action on each other: for, becauſe the fluid contained in B is united by attraction to the common matter, and is alſo repelled by the fluid in A, it neceſſarily follows, that the whole body B is repelled by the fluid in A. But, on the other hand, the matter in A attracts the fluid in B, and conſequently attracts the whole body B: Similar action is exerted by B on A. Theſe contrary forces are either equal, and deſtroy each other, or unequal, and one of them prevails. This equality or inequality evidently depends on the quantity of fluid contained in one or both of the bodies (n° 7.). Now it is known that bodies left entirely to themſelves neither attract nor repel; and it follows from the hypothetical pro-

perties of the fluid, that if there be either a redundancy or deficiency of fluid, there will be an efflux or influx, till the attractions and repulſions balance each other. Therefore the internal ſtate of two bodies which neither attract nor repel each other, is that where each contains its natural quantity of electric fluid.

In order, therefore, to conceive diſtinctly the ſtate of a body containing its natural quantity, and to have a diſtinct notion of this natural quantity, we muſt ſuppoſe that the quantity of fluid competent to a particle of matter in A repels the fluid competent to a particle of matter in B, juſt as much as it attracts that particle of matter; and alſo, that the fluid belonging to a particle of matter in A, repels the fluid belonging to a particle of matter in B, juſt as much as the particle of matter in A attracts it. Thus the whole fluid in the one repels the whole fluid in the other as much as it attracts the whole matter.

Since this muſt be conceived of every particle of common matter in a body, we muſt admit, that when a body is in its natural ſtate, the quantity of electric fluid in it is proportional to the quantity of matter, every particle being united with an equal quantity of fluid. This, however, does not neceſſarily require that different kinds of matter, in their natural or ſaturated ſtate, ſhall contain the ſame proportion of fluid. It is ſufficient that each contains ſuch a quantity, uniformly diſtributed among its particles, that its repulſion for the fluid in another body is equal to its attraction for the common matter in it. It is, however, more probable, for reaſons to be given afterwards, that the quantity of electric fluid attached, or competent, to a particle of all kinds of matter is the ſame.

We ſhall now conſider more particularly the immediate reſults of this hypotheſis, in the moſt ſimple caſes, from which we may derive ſome elementary propoſitions.

10 Electric phenomena ariſe from redundancy or deficiency in fluid, total or partial.

Since our hypotheſis is accommodated to the fact, that bodies in their natural ſtate, having their natural quantity of electric fluid, are altogether inactive on each other, by making this natural quantity ſuch, that its mutual repulſion exactly balances its attraction for the common matter—it follows, that we muſt deduce all the electric phenomena from a redundancy or deficiency of electric fluid. This accordingly is the Franklinian doctrine. The redundant ſtate of a body is called by Dr Franklin POSITIVE or PLUS ELECTRICITY, and the deficient ſtate is called NEGATIVE or MINUS ELECTRICITY.

A body may contain more than its natural quantity, or leſs, in every part, or it may be redundant in one place and deficient in another. Theſe different conditions will exhibit different appearances, which muſt be conſidered firſt of all.

11 Action of the redundant fluid or matter, how computed.

Let the body A (fig. 1.) be ſuppoſed in its natural ſtate throughout, which we ſhall generally expreſs by ſaying that it is SATURATED; and let us expreſs the quantity of fluid required for its ſaturation by the ſymbol Q. Let P be a ſuperficial particle of the fluid. It is attracted by the common matter of the body (which we ſhall in future call ſimply the *matter)*, and it is repelled equally by the fluid. Let us call the attraction a, and the repulſion r. Then the force with which the ſuperficial particle is attracted by the body, muſt be $= a - r$, and $a - r$ muſt be $= 0$, becauſe $a = r$. Let the quantity f of fluid be added to the body, and uniformly diſtributed through its ſubſtance. Then, becauſe we muſt admit that the action is in proportion to the quantity of acting fluid, and this is now $Q + f$, we have $Q : Q + f = r : \frac{\overline{Q+f} \times r}{Q}$; and therefore P is repelled by the whole fluid with the force, $\frac{\overline{Q+f} \times r}{Q}$ or $\frac{Qr}{Q} + \frac{fr}{Q}$, or $r + \frac{fr}{Q}$. But it is attracted by the common matter in the ſame manner as before, that is, with a force $= a$. Therefore the whole action on P is $= a - r - \frac{fr}{Q}$. But $a - r = 0$. Therefore the whole action on P is $= -\frac{fr}{Q}$; that is, P is repelled with the force $\frac{fr}{Q}$.

This will perhaps be as diſtinctly conceived by recollecting, that as much of the fluid as was neceſſary for ſaturation, that is, the quantity Q, puts the particle P in equilibrio; and therefore we need only conſider the action of the redundant fluid f. To find the repulſive force of this, ſay $Q : f = r : \frac{fr}{Q}$, and prefix the ſign $-$; becauſe we are to conſider attractions as poſitive, and repulſions as negative, quantities.

12 States of a body cauſing efflux or influx.

Unleſs, therefore, the particle P be withheld by ſome other force, it will quit the body, being expelled by a force $\frac{fr}{Q}$. And as every ſuperficial particle is in a ſimilar ſituation, we ſee that there will be an efflux from an overcharged body, till all the redundant fluid has quitted it. This efflux will indeed gradually diminiſh as the expelling force $\frac{fr}{Q}$ diminiſhes; that is, as f diminiſhes, but will never ceaſe till f be reduced to nothing. But if there be either an external force acting on the ſuperficial fluid in the oppoſite direction, or ſome internal obſtruction to its motion, the efflux will ſtop when the remaining expelling force is juſt in equilibrio with this external force, or this obſtruction.

13 On the other hand, if the body contains leſs than its natural quantity of fluid, there will be an influx from without; for if there be a deficiency of fluid $= f$, the particle P will be repelled with the force $\frac{\overline{Q-f} \times r}{Q}$, $= r - \frac{fr}{Q}$. It is attracted with the force a; and therefore the whole action is $= a - r + \frac{fr}{Q}$, $= +\frac{fr}{Q}$ (becauſe $a - r = 0$); that is, P is attracted with the force $\frac{fr}{Q}$. Fluid will therefore enter from all quarters, as long as there is any deficiency of the quantity neceſſary for ſaturation, unleſs it be oppoſed by ſome external force, or hindered by ſome internal obſtruction.

When there is a deficiency of fluid, there is a redundancy of matter, ſuch that its attraction for external fluid is equal to the repulſion of a quantity f of fluid. This confirms the aſſumption in n°. 10, that *the action of a body on the electric fluid depends entirely on the redundant fluid, or the redundant matter of the body.*

14 How bodies are ideo electrics or non-electrics. The efflux or influx may be prevented, either by ſurrounding the body with ſubſtances, through the pores of which the fluid cannot move at all, or by the body itſelf being of this conſtitution. And thus we ſee, that the very circumſtance of being impervious to the fluid, or completely permeable, renders the body capable or incapable of permanently exhibiting electrical phenomena, if ſurrounded by permeable bodies. This circumſtance alone, therefore, is ſufficient to conſtitute the difference between *electrics per ſe*, and *non-electrics*.— Here, then, is a numerous claſs of phenomena, which receive an explanation by this hypothetical conſtitution of the electric fluid. All electrics *per ſe* are bodies fit for confining electricity in bodies which are rendered capable (by whatever means) of producing electrical phenomena; and no conductor, or ſubſtance which allows the electricity to paſs through it, can be made electric by any of the means which produce that effect in *inſulators*. And it is well known, that the electricity of electrics is vaſtly more durable that that of non-electrics in ſimilar ſituations. It is true, indeed, that an electric, which has been excited ſo as to exhibit electric phenomena with great vivacity, loſes this power very quickly if plunged into water, or any other conducting body. But this is owing to the redundancy or deficiency being quite ſuperficial, ſo that the parts which are diſpoſed to give out or to take in the fluid are in immediate contact with the conducting matter. That the redundancy or deficiency is ſuperficial, follows from this hypotheſis; for when the ſurface is overcharged by the means employed for exciting, the impermeability of the electric *per ſe* prevents this redundant fluid from penetrating to any depth; and when the ſurface has been rendered deficient in fluid, the ſame impermeability prevents the fluid from expanding from the interior parts, ſo as to contribute to the repleniſhing the ſuperficial ſtratum with fluid. If, indeed, we could fall on any way of overcharging the interior parts of a glaſs ball, or of abſtracting the natural quantity from them, it is highly probable, that it would continue to attract or repel even after it had been plunged in water. Although the ſurrounding water would inſtantly take off the fluid redundant contained in the very ſurface, the repulſion of the fluid in the internal parts would ſtill be ſenſible: nay, if a very ſmall permeability be ſuppoſed, the body would again become overcharged at the ſurface; juſt as we ſee, that when we plunge a red-hot ball of iron into water, and take it out again immediately, it is black on the ſurface, and may be touched with the finger; but in half a minute after, it again becomes red-hot. Perhaps this may be accompliſhed with a globe of ſealing wax, which is permeable while liquid, by electrifying it in a particular way while in that ſtate, and allowing it to freeze. But the reader is not far enough advanced in the hypotheſis to underſtand the proceſs which muſt be followed. He cannot but recollect, however, many examples in coated glaſs, &c. where the electricity is moſt pertinaciouſly retained by a ſurface in very cloſe contact with conductors.

15 Conſequences of unequable diſtribution of fluid. 1. Action on external fluid. Let us now ſuppoſe a body NS (fig. 2.), containing in the half NA a quantity f of redundant fluid, and in the half AS let there be a deficiency g of fluid; that is, let there be a quantity of matter unſaturated, and ſuch as will attract fluid as much as the quantity g of fluid would repel it. Let the fluid neceſſary for the ſaturation of each half of NS be Q, as before. Let the attraction of the whole matter of NA for a particle of fluid at N be a; and let r be the repulſion exerted on the ſame particle N by the whole uniformly diſtributed fluid in NA and let r' be the repulſion exerted by the *ſame quantity* of fluid in the remote part SA. Then the force with which the particle N or S is attracted by the merely ſaturated body NS muſt be $= a - r - r'$. This is evidently nothing, if the body be in its natural ſtate. But as NA contains the redundant fluid f, and SA is deficient by the quantity g, the whole action muſt be $a - \frac{\overline{Q+f} \times r}{Q} - \frac{\overline{Q-g} \times r'}{Q}$. But becauſe $a - r - r' = o$, the action becomes $= \frac{g r' - f r}{Q}$, or becauſe r is greater than r', the particle N is repelled with the force $\frac{fr - gr'}{Q}$. In like manner, the particle S is attracted with the force $\frac{g r - f r'}{Q}$.

16 2. Action on the contained fluid. In the mean time, a particle C, ſituated at the middle, muſt be in equilibrio, if the body be in its natural ſtate, being equally attracted, and alſo equally repelled, on both ſides. But as we ſuppoſe that NA is overcharged with the quantity f, C muſt be repelled in the direction CS with the force $\frac{f r}{Q}$. And if we alſo ſuppoſe that AS is deficient by the quantity g, C is attracted in the direction CS with a force $\frac{g r}{Q}$. Therefore, on the whole, it is urged in the direction CS with the force $\frac{f r + g r}{Q}$, or $\frac{\overline{f+g} \times r}{Q}$.

17 It will be uniformly diffuſed, unleſs obſtructed. Hence we learn, that as long as there is any redundancy in AN, and deficiency in AS, there is a tendency of the redundant fluid to move from N toward S; and, if the body be altogether permeable by the electric fluid, we cannot have a permanent ſtate till the fluid is ſimilarly diſtributed, and equally divided, between the two halves of NS. Therefore a ſtate like that aſſumed in this example cannot be permanent in a conducting body, unleſs an external force act on it; but it may ſubſiſt in a non-conductor, and in a leſſer degree, in all imperfect conductors.

18 Nature of the obſtruction. It is neceſſary, in this place, to conſider a little the nature of that reſiſtance which muſt be aſſigned to the motion of the electric fluid through the pores of the body. If it reſemble the reſiſtance oppoſed by a perfect fluid, ariſing ſolely from the inertia of its particles, then there is no inequality of force ſo minute but that it will operate a uniform diſtribution of the fluid, or at leaſt a diſtribution which will make the exceſs of the mutual attractions and repulſions preciſely equal and oppoſite to the external force which keeps it in any ſtate

of unequal diſtribution. But it may reſemble the reſiſtance to the deſcent of a parcel of ſmall ſhot diſſeminated among a quantity of grain, or the reſiſtance to motion through the pores of a plaſtic or ductile body, ſuch as clay or lead. Here, in order that a particle may change its place, it muſt overcome the tenacity of the adjoining particles of the body. Therefore, when an unequal diſtribution has been produced by an external force, the removal or alteration of that force will not be followed by an equable diſtribution of the fluid. In every part there will remain ſuch an inequality of diſtribution, that the want of equilibrium between the electric attractions or repulſions is balanced by the tenacity of the parts.

19 We learn farther from the foregoing propoſitions, that a particle at N is leſs repelled than if the part AS were overcharged as AN is: for in that caſe, it would be expelled by a force $\frac{f\times\overline{r+r'}}{Q}$, which is much greater than $\frac{fr-gr'}{Q}$. And, in like manner, the particle S is attracted with leſs force than it would be if NA were equally undercharged with SA.

20 The condition of the body now deſcribed may be changed by different methods. The redundant fluid in AN may flow into AS, where it is deficient, till the whole be uniformly diſtributed; or fluid may eſcape from AN, and fluid may enter into AS, till the body be in its natural ſtate. The firſt method will be ſo much the ſlower, as the body is leſs permeable, or more remarkably *electric per ſe*; and the ſecond method will be ſlower than if the whole body were overcharged or undercharged.

21 What we have been now ſaying of a body NS that is overcharged at one end, and undercharged at the other, and capable of retaining this ſtate, is applicable, in every particular, to two conducting bodies, NA and SA′, having a non-conducting body Z interpoſed between them, as in fig. 3. All the formulas or expreſſions of the forces which tend to expel or to draw in fluid, are the ſame as before. Perhaps this is the beſt way of forming to ourſelves a diſtinct notion of the body that is redundant in fluid at one end, and deficient at the other. And we perceive, that the ſtate of the two bodies, ſeparated by the electric Z, will be more permanent when one is overcharged, and the other undercharged, than if both are either over or undercharged.

22 A body may be inactive, or neutral, where it is redundant or deficient. It muſt be remarked, that the quantities f and g were taken at random. They may be ſo taken, that the force with which the fluid tends to eſcape at N, or to enter at S, may be nothing, or may even be changed to their oppoſite. Thus, in order that there may be no tendency to eſcape from N, we have only to ſuppoſe $gr'-fr=0$, or $g:f=r:r'$, and $g=\frac{fr}{r'}$. In this caſe, the particle at N is as much attracted by the redundant matter in SA as it is repelled by the redundant fluid in NA.

23 Conditions neceſſary for this. When the extremity N is rendered inactive in this manner, the condition of the other extremity S is conſiderably changed. To diſcover this condition, put $\frac{fr}{r'}$ in place of g in the formula $\frac{gr-fr'}{Q}$, which expreſſes the attraction for a particle at S, and we obtain $\frac{f\times\overline{r^2-r'^2}}{Qr'}$.

24 On the other hand, we may have the redundancy and deficiency ſo balanced, that there ſhall be no tendency to influx at S. For this purpoſe, we muſt make $g=\frac{fr'}{r}$. When this obtains at S, the action at N will be had by putting $\frac{fr'}{r}$ in place of g in the formula $\frac{fr-gr'}{Q}$, and this will give us $\frac{f\times\overline{r'^2-r^2}}{Qr}$ for the force repelling a particle at N.

25 When the tendency to efflux or influx is induced in this manner, by a due proportion of the redundancy and deficiency of electric fluid, the part of the body where this obtains is by no means in its natural ſtate, and may contain either more or leſs than its natural quantity. But it neither acts like an overcharged, nor like an undercharged body, and may therefore be called NEUTRAL. The reader who is converſant with electrical experiments, will recollect numberleſs inſtances of this, and will alſo recollect that they are important ones. Such, for example, is the caſe with the plates and covers of the electrophorus. Theſe circumſtances, therefore, claim particular attention.

26 As the quantities f and g may be ſo choſen, that the apparatus ſhall be *neutral*, either at S or at N; they may likewiſe be ſo, that either end ſhall exhibit either the appearance of *redundancy* or *deficiency*. Thus, inſtead of neutrality at N, we may have repulſion, as at the firſt, by making g leſs in any degree than $\frac{fr}{r'}$. If, on the contrary, g be greater than $\frac{fr}{r'}$, the extremity N, though overcharged, will attract fluid. In like manner, if g be leſs than $\frac{fr'}{r}$, the extremity S, although undercharged, will repel fluid.—We may make the following general remarks.

27 Both ends cannot be neutral at once. 1. Both extremities N and S cannot be neutral at the ſame time: for ſince the neutrality ariſes from the increaſed quantity of redundancy or deficiency at the other extremity, ſo as to compenſate for its greater diſtance, the activity of that extremity muſt be proportionably greater on the fluid adjoining to its ſurface, whether externally or internally. When an overcharged extremity is rendered neutral, the other extremity attracts fluid more ſtrongly; and when a deficient extremity is rendered neutral, the other repels fluid more ſtrongly. All theſe elementary corollaries will be fully verified afterwards, and give clear explanations of the moſt curious phenomena.

2. We have been ſuppoſing, that the redundant fluid is uniformly ſpread, and that the body is divided into equal portions; but this was merely to ſimplify the procedure and the formulæ. The reader muſt ſee, that the general concluſions are not affected by this, and that ſimilar formulæ will be obtained, whatever is the diſpoſition of the fluid. We cannot tell in what manner the redundant fluid is diſpoſed, even in a body of the ſimpleſt form, till we know what is the variation of its attraction and repulſion by a change of diſtance; and even when this has been diſcovered, we find it difficult

in moſt caſes, and impoſſible in many, to aſcertain the mode of diſtribution. We ſhall learn it in ſome important caſes, by means of various phenomena judiciouſly ſelected.

28 A body may be conſidered in many diviſions, in ſome of which the fluid is redundant, and in others deficient. We may expreſs the repulſion of the whole of this body in the ſame way as we expreſs that of a body conſidered in two diviſions, uſing the letters f, g, h, &c. to expreſs the quantities of redundant or deficient fluid in each portion, while Q expreſſes the quantity neceſſary for ſaturating each of them; and the repulſion at different diſtances may be expreſſed by r, r', r'', r''', &c. as they are more and more remote; and we may expreſs their action as attractive or repulſive by prefixing the ſign + or —. Thus the attraction may be $\frac{(f r - g r' + h r'' - i r''')}{Q}$, &c.

29 Senſible actions of electrical bodies.

Having obtained the expreſſions of the inviſible actions of electrified bodies on the fluid within them, or ſurrounding them, let us now conſider their ſenſible actions on other bodies, producing motion, or tendencies to motion.

Here it is obvious, that the mechanical phenomena exhibited are what may be called *remote* EFFECTS of the acting forces. The immediate effects, or the mutual actions of the particles are not obſerved, but hypothetically inferred. The tangible matter of the body is put in motion, in conſequence of its connection with the fluid reſiding in the body, which fluid is the only ſubject of the action of the other body.

In conſidering theſe phenomena, we ſhall content ourſelves with a more general view of the actions which take place between the fluid or tangible matter of the one body, and the fluid or matter of the other, ſo as to gain our purpoſe by more ſimple formulæ than thoſe hitherto employed. They were premiſed, however, becauſe we *muſt* have recourſe to them on many very important particular occaſions.

30 Let there be two bodies, A and B, in their natural ſtate. Let the tangible matter in A be called M, and let the fluid neceſſary for its ſaturation be called F, and let m and f be the tangible matter and the fluid in B. Let the mutual action between a ſingle particle of fluid and the matter neceſſary for its ſaturation be expreſſed by the intermediate ſymbol z, becauſe it varies by a change of diſtance.

The actions are mutual and equal. Therefore when the motion of B by the action of A is determined, the motion of A is alſo aſcertained. We ſhall therefore only conſider how A is affected. 1. Every particle of fluid in A tends toward every particle of matter in B with the force z. The whole tendency of A toward B may therefore be expreſſed by z, multiplied by the product F and m. 2. Every particle of fluid in A is repelled by every particle of fluid in B, with the ſame force z. 3. Every particle of matter in A is attracted by every particle of fluid in B, with the ſame force. We may expreſs this more purely and briefly thus:

1. F tends *toward* m with the force $+ F m z$
2. F tends *from* f with the force $- F f z$
3. M tends *toward* f with the force $+ M f z$

Therefore the ſenſible tendency of A to or from B will be $= z \times \overline{F m + M f - F f}$. But, by the hypotheſis, the attraction of a particle of the fluid in A for a particle of the matter in B, is equal to its repulſion for the particle or parcel of the fluid attached or competent to that particle of matter. Therefore the attraction $F m z$ is balanced by the repulſion $F f z$. Therefore there remains the attraction of the matter in A for the fluid in B unbalanced, and the body A will tend toward the body B with the force $M f z$, or B attracts A with the force $M f z$. A muſt therefore move toward B. And, by the 3d law of motion, B muſt move toward A with equal force.

31 Completion of the hypotheſis of Æpinus.

But the fact is, that no tendency of any kind is obſerved between bodies in their natural ſtate. The hypotheſis, therefore, is not complete. If we abide by it, as far as it is already expreſſed, we muſt farther ſuppoſe, that there is ſome repulſive force exerted between the bodies to balance the attraction of M for f. Mr Æpinus, therefore, ſuppoſes, that every particle of tangible matter repels another particle as much as it attracts the fluid neceſſary for its ſaturation. The whole action of B on A will now be $= z \times \overline{F m - F f - M m + M f}$. $F m z$ is balanced by $F f z$, and $M m z$ by $M f z$, and no exceſs remains on either ſide.

32 Objections anſwered.

Æpinus acknowledges, that this circumſtance appeared to himſelf to be hardly admiſſible; it ſeeming inconceivable, that a particle in A ſhall repel a particle in B, or tend from it, electrically, while it attracts it, or tends toward it, by planetary gravitation. We cannot conceive this; but more attentive conſideration ſhewed him, that there is nothing in it contrary to the obſerved analogy of natural operations. We muſt acknowledge, that we ſee innumerable inſtances of inherent forces of attraction and repulſion; and nothing hinders us from referring this lately diſcovered power to the claſs of primitive and fundamental powers of nature. Nor is there any difficulty in reconciling this repulſion with univerſal gravitation; for while bodies are in their natural ſtate, the electric attractions and repulſions preciſely balance each other, and there is nothing to diſturb the phenomena of planetary gravitation; and when bodies are not in their natural electrical ſtate, it is a fact that their gravitation is diſturbed. Although we cannot conceive a body to have a tendency to another body, and at the ſame time a tendency from it, when we derive our notion of theſe tendencies entirely from our own conſciouſneſs of effort, endeavour, *conatus, niſus accedendi ſeu recedendi*, nothing is more certain than that bodies exhibit at once the appearances which we endeavour to expreſs by theſe words. We can bring the north poles of two magnets near each other, in which caſe they recede from each other; and if this be prevented by ſome obſtacle, they preſs on this obſtacle, and ſeem to endeavour to ſeparate. If, while they are in this ſtate, we electrify one of them, we find that they will now approach each other; and we have a diſtinct proof that both tendencies are in actual exertion by varying their diſtances, ſo that one or other force may prevail; or by placing a third body, which ſhall be affected by the one but not by the other, &c. We do not underſtand, nor can conceive in the leaſt, how either force, or how gravity, reſides in a body; but the effects are paſt contradiction. It muſt be granted, therefore, that this additional circumſtance of Æpinus's hypotheſis has nothing in it that is repugnant to the obſerved phenomena of nature.

N. B. It is not neceſſary to ſuppoſe (although Mr Æpinus does ſuppoſe it), that every atom of tangible matter repels every other atom. It will equally explain all the phenomena, if we ſuppoſe that every particle contains an atom or ingredient having this property, and that it is this atom alone which attracts the particles of electrical fluid. The material atoms having this property, and their correſponding atoms of fluid, may be very few in compariſon with the number of atoms which compoſe the tangible matter. Their mutual ſpecific action being very great in compariſon with the attraction of gravitation (as we certainly obſerve in the action of light), all the phenomena of electricity will be produced without any ſenſible effect on the phenomena of gravitation, even although neither the electric fluid nor its ally, this ingredient of tangible matter, ſhould not gravitate. But this ſuppoſition is by no means neceſſary.

Since we call that the natural electrical ſtate of bodies in which they do not affect each other, and the hypothetical powers of the fluid are accommodated to this condition, we may conſider any body that has more than its natural quantity as conſiſting of a quantity of matter ſaturated with fluid, and a quantity of redundant fluid ſuperadded; and an undercharged body may be conſidered as conſiſting of a quantity of matter ſuperadded. The ſaturated matter of theſe two bodies will be totally inactive on another body in its natural ſtate, and will neither attract nor repel it, nor be attracted nor repelled by it; therefore the action of the overcharged body will depend entirely on the redundant fluid; and that of the undercharged body will depend entirely on the redundant matter; therefore we need only conſider them as conſiſting of this redundant fluid or matter, agreeably to what was ſaid in more vague terms in nº 10. and 13. This will free us from the complicated formulæ which would otherwiſe be neceſſary for expreſſing all the actions of the fluid and tangible matter of two bodies on each other. The reſults will be ſufficiently particular for diſtinguiſhing the ſenſible action of bodies in the chief general caſes; but in ſome particular and important caſes, it is abſolutely neceſſary to employ every term.

33 General expreſſion (ſymbolical) of the mutual action.

1. Suppoſe two bodies A and B, containing the quantities F' and f' of redundant fluid, it is plain that their mutual action is expreſſed by $F' \times f' + z$, and that it is a repulſion; for ſince every particle of redundant fluid in A repels every particle of redundant fluid in B with the force z; and ſince F' and f' are the numbers of ſuch particles in each, the whole repulſion muſt be expreſſed by the product of theſe numbers.

34 2. In like manner, two bodies A and B, containing the redundant matter M' and m', will repel each other with the force $M' m' z$.

35 3. And two bodies A and B, one of which A contains the redundant fluid F', and the other B contains the redundant matter m', will attract each other with the force $F m' z$.

36 4. It follows from theſe premiſes, that if either of the bodies be in its natural ſtate, they will neither attract nor repel each other; for, in ſuch a caſe, one of the factors F', or f', or M', or m', which is neceſſary for making a product, is wanting. This may be perceived independent of the mathematical formula; for if A contain redundant fluid, and B be in its natural ſtate, every particle of the redundant fluid in A is as much repelled by the natural fluid in B as it is attracted by the tangible matter.

37 Seeming paradox.

The three firſt propoſitions agree perfectly with the known phenomena of electricity; for bodies repel each other, whether both are poſitively or both are negatively electrified, and bodies always attract each other when the one is poſitively and the other negatively electrified. But the fourth caſe ſeems very inconſiſtent with the moſt familiar phenomena. Dr Franklin and all his followers aſſert, on the contrary, that electrified bodies, whether poſitive or negative, always attract, and are attracted, by all bodies which are in their natural ſtate of electricity. But it will be clearly ſhewn preſently, that they are miſtaken, and that Franklin's theory neceſſarily ſuppoſes the truth of the fourth propoſition, otherwiſe two bodies in their natural ſtate could not be neutral or inactive, as any one may perceive on a very ſlight examination by the Franklinian principles. It will preſently appear, with the fulleſt evidence; and, in the mean time, we proceed to explain the action of bodies which are overcharged in ſome part, and undercharged in another.

38 Action of a body having the fluid unequably diſpoſed.

Let the body B (fig. 4.) be overcharged in the part B n, and undercharged in the part B s, and let f' and m' be the redundant fluid and common matter in thoſe parts; let A be overcharged, and contain the redundant fluid F'; let z and z' expreſs the intenſity of action correſponding with the diſtances of A from the overcharged and undercharged parts of B; the part B n repels A with the force $F' f' z$, while the part B s attracts it with the force $F' m' z$: A will therefore be attracted or repelled by B, according as $F m' z'$ is greater or leſs than $F' f' z'$; that is, according as $m' z'$ is greater or leſs than $f' z$. This, again depends on the proportion of f' to m', and on the proportion of z to z'. The firſt depends on many external circumſtances, which may occaſion a greater or leſs redundancy or deficiency of electrical fluid; the ſecond depends entirely on the law of electric attraction and repulſion, or the change produced in its intenſity by a change of diſtance. As we are, at preſent, only aiming at very general notions, it is enough to recollect, that all the electric phenomena, and indeed the general analogy of nature, concur in ſhewing that the intenſity of both forces (attraction and repulſion) decreaſes by an increaſe of diſtance; and to combine this with that circumſtance of the hypotheſis which ſtates the repulſion to be equal to the attraction at the ſame diſtance; therefore both forces vary by the ſame law, and we have z always greater than z'. The viſible action of B on A (which, by the 3d law of motion, is accompanied by a ſimilar action of A on B) may be various, even with one poſition of B, and will be changed by changing this poſition.

Caſes of ſenſible repulſion.

1. We may ſuppoſe that B contains, on the whole, its natural quantity, but that part of it is abſtracted from B s, and is crowded into B n. This is a very common caſe, as we ſhall ſee preſently, and it will be expreſſed in our formula by making $f' = m'$. In this caſe, therefore, we have $F' f' z$ greater than $F' m' z$,

becauſe z is greater than z'. A will therefore be repelled by B, and will repel it; and the repulſion will be $F' f' \times \overline{z - z'}$.

Of attraction.

It is evident, that if A be placed on the other ſide of B, the appearances will be reverſed, and the bodies will attract each other with the force $F' f' \times \overline{z - z'}$.

It is alſo plain, that if A be as much undercharged as we have ſuppoſed it overcharged, all the appearances will be reverſed; if on the undercharged ſide of B, it will be repelled; and if on the overcharged ſide of B, it will be attracted.

39 Of Neutrality.

2. If the redundancy and deficiency in the two portions of B be inverſely proportional to the forces, ſo that $F' : m' = z' : z$, we ſhall have $f' z = m' z'$, and $m' = \frac{f' z}{z'}$. In this caſe theſe two actions balance each other, and A is neither attracted nor repelled when at this preciſe diſtance from the overcharged ſide of B. B may be ſaid to be NEUTRAL with reſpect to A, although A and the adjoining ſide of B are both overcharged.

40 Bodies neutral at one end are more active at the other.

But if A be placed at the ſame diſtance on the other ſide of B, the effect will be very different: For becauſe $m' = \frac{f' z}{z'}$, and $m' z'$ is now changed into $m' z$, and $f' z$ into $f z'$, we have the action on A $= F' \times \left(\frac{f' z}{z'} - f' z'\right), = F' f' \times \frac{z^2 - z'^2}{z'}$; that is, A is ſtrongly attracted.

In like manner, f' and m' may be ſo proportioned, that when A, containing redundant fluid, is placed near the undercharged end of s B, it ſhall neither be attracted nor repelled, B becoming neutral with regard to A at that preciſe diſtance. For this purpoſe m' muſt be $= \frac{f z'}{z}$. And if A be now placed at the ſame diſtance on the other ſide of B, it will be repelled with the force $F' f' \times \frac{z^2 - z'^2}{z}$.

Thus, when the overcharged end is rendered neutral to an overcharged body, the other end ſtrongly attracts it; and when the undercharged end is rendered neutral to the ſame body, the overcharged end ſtrongly repels it.

Similiar appearances are exhibited when A is undercharged.

Theſe caſes are of frequent occurrence, and are important, as will appear afterwards.

41 It is eaſy now to ſee what changes will be made on the action of B on A, by changing the proportion of f' and m'. If m' be made greater than $\frac{f' z}{z'}$, A will be attracted in the ſituation where it was formerly neutral; and if m' be made leſs, A will be repelled, &c. &c.

Therefore, when we obſerve B to be neutral, or attractive, or repulſive, we muſt conclude that m' is equal to $\frac{f z}{z'}$, or greater or leſs than it, &c.

We have been thus minute, that the reader may perceive the agreement between this action on a body containing redundant fluid, and the action on the ſuperficial fluid formerly conſidered in n° 21, 22, 23, 24. When theſe things are attended to, we ſhall explain, with great eaſe, all the curious phenomena of the electrophorus.

42 Neutrality generally limited to a preciſe diſtance. Important information obtained from this.

There is another circumſtance to be attended to here, which will alſo explain ſome electrical appearances that ſeem very puzzling. We limited the inactivity of B to a certain preciſe diſtance of the body A. This inactivity required that m' ſhould be $= \frac{f z}{z'}$. If A be brought nearer, both z and z' are increaſed. If they are both increaſed in the ſame proportion, the value of $\frac{z}{z'}$ will be the ſame as before, and the body A will neither be attracted nor repelled at this new diſtance. But if z increaſe faſter than z', we ſhall have $f' z$ greater than $m' z'$, and A will be repelled; and if z increaſes more ſlowly than z', A will be attracted by bringing it nearer. The contrary effects will be obſerved if A be removed farther from the overcharged end of B. This explains many curious phenomena; and thoſe phenomena become inſtructive, becauſe they enable us to diſcover the law of electric action, by ſhewing us the manner in which it diminiſhes by a change of diſtance. Electricians cannot but recollect many inſtances, in which the motion of the electrometer appeared very capricious. The general fact is, that when an overcharged pith ball is ſo ſituated near the overcharged ſide of the electrophorus as to be neutral, it is repelled when brought nearer, but attracted when removed to a greater diſtance. This ſhews that z increaſes faſter than z' when A is brought nearer to B. Now, ſince the bodies may be again rendered neutral at a greater diſtance than before, and the ſame appearances are ſtill obſerved, it follows, that the law of action is ſuch, that *every* diminution of diſtance cauſes z to increaſe faſter than z'. We ſhall find this to be valuable information.

43 Action when the fluid is unequably diſpoſed in both bodies.

Let us, in the laſt place, inquire into the ſenſible effect on A when it alſo is partly overcharged and partly undercharged. This is a much more complicated caſe, and is ſuſceptible of great variety of external appearances, according to the degrees of redundancy and deficiency, and according to the kind of electricity (poſitive or negative) of the ends which front each other.

44 Firſt, then, let the overcharged end of A (fig. 5.) front the undercharged end of B, they being overcharged in N and n, but undercharged in S and s. Let F and f be the quantity of fluid natural to each; and let F' and f' be the redundancy in N and n, and M' and m' the deficiency in S and s. Moreover, let Z and Z' repreſent the intenſity of actions of a particle in N on a particle in n and s; and let z and z' repreſent the actions of a particle in S on a particle in n and in s; or, in other words, let Z, Z', z, z', repreſent the intenſity of action between particle and particle, correſponding to the diſtances N s, N n, S s, S n.

Proceeding in the ſame manner as in the former examples, we eaſily ſee, that the action of B on A is $= \frac{F' m' Z - F' f' Z' - M' m' z + M' f' z'.}{F f}$; the attractions are conſidered as poſitive quantities, having the ſign + prefixed to them, and the repulſions are negative, having the ſign —.

This action will be either attractive or repulſive, according as the ſum of the firſt and laſt terms of the numerator exceeds or falls ſhort of the ſum of the ſecond and third: And the value of each term will be greater or leſs, according to the quantity of redundant fluid and matter, and alſo according to the intenſity of the electric action. It would require ſeveral pages to ſtate all thoſe poſſible varieties. We ſhall therefore content ourſelves at preſent with ſtating the ſimpleſt caſe; becauſe a clear conception of this will enable the reader to form a pretty diſtinct notion of the other poſſible caſes; and alſo, becauſe this caſe is very frequent, and is the moſt uſeful for the explanation of phenomena.

We ſhall ſuppoſe, that the redundant part of each body is juſt as much overcharged as the deficient part is undercharged; ſo that $F' = M'$, and $f' = m'$. In this caſe, the formula becomes $\frac{F'f'(Z - Z' - z + z')}{F f}$.

Uſeful repreſentation of the mutual forces by ordinates to a curve.

Here we ſee that the ſenſible or external effect on A depends entirely on the law of electric action, or the variation of its intenſity by a change of diſtance. If the ſum of Z and z' exceed the ſum of Z' and z, A will be attracted; but if $Z + z'$ be leſs than $Z' + z$, A will be repelled. This circumſtance ſuggeſts to us a very perſpicuous method of expreſſing theſe actions between particle and particle, ſo that the imagination ſhall have a ready conception of the circumſtance which determines the external complicated effect of this internal action. This will be obtained by meaſuring off from a fixed point of a ſtraight line portions reſpectively equal to the diſtances N *s*, N *n*, S *s*, and S *n*, between the points of the two bodies A and B, where we ſuppoſe the forces of the redundant fluid and redundant matter to be concentrated, and erect ordinates having the proportion of thoſe forces. If the law of action be known, even though very imperfectly, we ſhall ſee, with one glance, of which kind the movements or tendencies of the bodies will be. Thus, in fig. 5. drawing the line C *z*, take C *p* = N *s*, C *q* = N *n*, C *r* = S *s*, and C *t* = S *n*, and erect the ordinates P *p*, Q *q*, R *r*, and T *t*. If the electric action be like all the other attractions and repulſions which we are familiarly acquainted with, decreaſing with an increaſe of diſtance, and decreaſing more ſlowly as the diſtances are greater, theſe ordinates will be bounded by a curve PQRTZ, which has its convexity turned toward the axis. We ſhall preſently get full proof that this is the caſe here; but we premiſe this general view of the ſubject, that we may avoid the more tedious, but more philoſophical, proceſs of deducing the nature of the curve from the phenomena now under conſideration.

45 General character of the ſcale of electric force.

This conſtruction evidently makes the pair of ordinates P *p*, Q *q*, equidiſtant with the pair R *r*, T *t*. Alſo, P *p*, R *r*, and Q *q*, T *t*, are equidiſtant pairs. It is no leſs clear, that the ſum of P *p* and T *t*, exceeds the ſum of Q *q* and R *r*. For if C *z* be biſected in V, and V *v* be drawn perpendicular to it, cutting the ſtraight lines PT and QR in *x* and *y*, then *x v* is the half ſum of P *p* and T *t*, and *y v* is the half ſum of Q *q* and R *r*. Moreover, if Q *m* and T *n* are drawn parallel to the baſe, we ſee that P *m* exceeds R *r*; and, in general, that if any pair of equidiſtant ordinates are brought nearer to C, their difference increaſes, and *vice verſa*. Alſo, if two pairs of equidiſtant ordinates be brought nearer to C, each pair by the ſame quantity, the difference of the neareſt pair will increaſe more than the difference of the more remote pair. And this will hold true, although the firſt of the remote pair ſhould ſtand between the two ordinates of the firſt pair. If the reader will take the trouble of conſidering theſe ſimple conſequences with a little attention, he will have a notion of all the effects that are to be expected in the mutual actions of the two bodies, ſufficiently preciſe for our preſent purpoſe. We ſhall give a much more accurate account of theſe mathematical truths in treating the article Magnetism, where preciſion is abſolutely neceſſary, and where it will be attended with the greateſt ſucceſs in the explanation of phenomena.

46 Now let us apply this to our preſent purpoſe. *Firſt*, then, When the overcharged end of A is turned toward the undercharged end of B, A muſt be attracted; for P *p* + T *t* is greater than Q *q* + R *r*.

47 *Secondly*, This attraction muſt increaſe by bringing the bodies nearer; for this will increaſe the difference between P *m* and R *n*.

48 *Thirdly*, The attraction will increaſe by increaſing the length either of A or of B (the diſtance N *s* remaining the ſame); for by increaſing the length of A, which is repreſented by *p r* or *q t*, R *r* is more diminiſhed than T *t* is. In like manner, by increaſing B, whoſe length is repreſented by *p q* or *r t*, we diminiſh Q *q* more than T *t*.

49 Uſe of this picture of the forces.

On the other hand, if the overcharged end of B front the overcharged end of A, their mutual action will be

$$\frac{F'f'(-Pp + Qq + Rr - Tt),}{Ff}$$

and A will be repelled, and the repulſion will increaſe or diminiſh, by change of diſtance or magnitude, preciſely in the ſame manner that the attractions did. It is hardly neceſſary to obſerve, that all theſe conſequences will reſult equally from bringing an apparatus ſimilar to that repreſented in fig. 3. near to another of the ſame kind; and that they will be various according to the poſition and the redundancy or deficiency of the two parts of each apparatus.

50 Curious phenomena which ſhould reſult from the hypotheſis reſembling magnetiſm.

If the body B of fig. 5, is not at liberty to approach toward A, nor to recede from it, and can only turn round its centre B, it will arrange itſelf in a certain determinate poſition with reſpect to that of A. For example, if the centre B (fig. 7.) be placed in the line paſſing through S and N of the body A, B will arrange itſelf in the ſame ſtraight line: for if we forcibly give it another poſition, ſuch as *s* B *n*, N will attract *s* and repel *n*, and theſe actions will concur in putting B into the poſition *s'* B *n'*. S, however, will repel *s* and attract *n*; and theſe forces tend to give the contrary poſition. But S being more remote than N, the former forces will prevail, and B will take the poſition *s'* B *n'*.

If the centre B be placed ſomewhere on the line AD, drawn through a certain point of the body NAS (which will be determined afterwards), at right angles to NAS, the body B will aſſume the poſition *n'* B *s'*, parallel to NAS, but ſubcontrary. For if we forcibly give it any other poſition *n* B *s*, it is plain that N repels *n* and attracts *s*, while S attracts *n* and repels *s*. Theſe four forces evidently combine to turn the body round its centre, and cannot balance each other till B aſſume the poſition *n'* B *s'*, where *n'* is next to S, and *s'* is next to N.

Form of the electric meridian.

If the centre of B have any other ſituation, ſuch as B′, the body will arrange itſelf in ſome ſuch poſition as *n'* B′ *s'*. It may be demonſtrated, that if B be infinitely ſmall, ſo that the action of the end of A on each of its extremities may be conſidered as equal, B will arrange itſelf in the tangent BT of a curve NB'S, ſuch that if we draw NB', SB, and from any point T of the tangent draw TE parallel to BN, and TF parallel to B'S, we ſhall have BE to BF, as the force of S to the force of N. This arrangement of B will be ſtill more remarkable and diſtinct if N be an overcharged ſphere, and S an undercharged one, and both be inſulated. We muſt leave it to the reader's reflection to ſee the changes which will ariſe from the inequality of the redundancy and deficiency in A or B, or both, and proceed to conſider the conſequences of the mobility of the electric fluid. Theſe will remove all the difficulty and paradox that appears in ſome of the foregoing propoſitions.

51
Conſequence (fundamental) of the mobility of the fluid in the pores of bodies.

Let the body A (fig. 4.) contain redundant fluid, and let B be in its natural ſtate, but let the fluid in A be fixed, and that in B perfectly moveable; it is evident that the redundant fluid in A will repel the moveable fluid in B, toward its remote extremity n, and leave it undercharged in s. The fluid will be rarefied in s, and conſtipated in n. We need only conſider the mutual actions of the redundant fluid and redundant matter. It is plain that things are now in the ſituation deſcribed in n° 15.: A muſt be attracted by B, becauſe $f' = m'$, and z is greater than z'. The attractive force is $F'f' \times (z-z')$.

Bodies containing the natural quantity, in the natural ſtate, attract and are attracted by electrified bodies,

Thus we ſee that the hypotheſis is accommodated to the phenomena in the caſe in which it appeared to differ ſo widely from it. Had the fluid been immoveable, the mutual actions would have ſo balanced each other that no external effects would have appeared. But now the greater vicinity of the redundant matter prevails, A is attracted by B, and, the actions being all mutual, B is attracted by A, and approaches it.

52
And change the ſtate of thoſe bodies, which increaſes attraction.

We have ſuppoſed that the fluid in A is immoveable; but this was for the ſake of greater ſimplicity. Suppoſe it moveable. Then, as ſoon as the uniform diſtribution of the fluid in B is changed, and B becomes undercharged at s, and overcharged at n, there are forces acting on the fluid in A, and tending to change its ſtate of diſtribution. The redundant matter in S attracts the redundant fluid in A more than the more remote redundant fluid in n repels it, becauſe z' is leſs than z. This tends to conſtipate the redundant fluid of A in the nearer parts, and render N more redundant, and S leſs redundant in fluid than before. It is plain, that this muſt increaſe their mutual action, without changing its nature. It can be ſtrictly demonſtrated, that however ſmall the redundancy in A may be, it can never be rendered deficient in its remote extremity by the action of the unequally diſpoſed fluid in B, if the fluid in B be no more nor leſs than its natural quantity. It is alſo plain, that this change in the diſpoſition of the fluid in A muſt increaſe the ſimilar change in B. It will be ſtill more rarefied in s, and condenſed in n; and this will go on in both till all is in equilibrio. When things are in this ſtate, a particle of fluid in B is in equilibrio by the combined action of ſeveral forces. The particle B is propelled toward n by the action of the redundant fluid in A. But it is urged toward S by the repulſion of the redundant fluid on the ſide of n, and alſo by the attraction of the redundant matter on the ſide of s; and the repulſion of the redundant fluid in A muſt be conceived as balancing the united action of thoſe two forces reſiding in B.

53
General notion of the forced diſpoſition of electric fluid in a body.

Hence we may conclude, that the denſity of the fluid in B will increaſe gradually from s to n. It will be extremely difficult to obtain any more preciſe idea of its denſity in the different parts of B, even although we knew the law of action between ſingle particles.

This muſt depend very much on the form and dimenſions of B; for any individual particle ſuſtains the ſenſible action of all the redundant fluid and redundant matter in it, ſince we ſuppoſe it affected by the more remote fluid in A. All that we can ſay of it in general is, that the denſity in the vicinity of s is leſs than the natural denſity; but in the vicinity of n it is greater; and therefore there muſt be ſome point between s and n where the fluid will have its natural denſity. This point may be called a NEUTRAL point. We do not mean by this that a particle of ſuperficial fluid will neither be attracted nor repelled in this place. This will not always be the caſe (although it will never be *greatly* otherwiſe); nor will the variation of the denſity in the different parts of B be proportional to the force of A on thoſe parts. Some eminent naturaliſts have been of this opinion; and, having made experiments in which it appeared to be otherwiſe, they have rejected the whole theory. But a little reflection will convince the mathematician, that the ſum of the internal forces which tend to urge a particle of fluid from its place, and which are balanced by the action of A, are *not* proportional to the variations of denſity, although they increaſe and decreaſe together. We ſhall take the proper opportunity of explaining thoſe experiments; and will alſo conſider ſome ſimple, but important caſes, where we think the law of diſtribution of the fluid aſcertained with tolerable preciſion.

Neutral point.

If we ſuppoſe, on the other hand, that A is undercharged, the redundant matter in A will attract the moveable fluid in B, and will abſtract it from the remote extremity, and crowd it into the adjacent extremity. Moreover, the fluid now becoming redundant in the nearer extremity of B, will act more ſtrongly on the moveable fluid in A than the more remote redundant matter of B; and thus fluid will be propelled toward the remote ſide of A, which will become now undercharged in its nearer ſide, and leſs undercharged in its remote ſide than if B were taken away. This muſt increaſe the inequability of diſtribution of the fluid in B, and both will be put farther from their natural ſtate; but A will never become overcharged in its remote extremity.

Things being in this ſtate, it is plain that A and B will mutually attract each other in the ſame manner, and with the ſame force, as when A was as much overcharged as it is now undercharged.

54
Electric atmoſphere is not adequate to the explanation of the phenomena.

Thus, then, we ſee how the attraction obtains, whether A be over or undercharged. A fact which Dr Franklin could never explain to his own ſatisfaction; nor will it ever be explained conſiſtently with the acknowledged principles and obſerved laws of mechanics by any perſon who employs electric atmoſpheres for this purpoſe. It is indeed a ſufficient objection to the employment of ſuch electric or other atmoſpheres, that the ſame extent of attraction and repulſion between the particles of the atmoſphere is neceſſary, as is employed here between the particles of the fluid reſiding in the body; and therefore they ceaſe to give any explanation,

even

it. This may, in like manner, produce a rarefaction farther on, followed by another condenſation; and this may be frequently repeated when the obſtruction is very great, and the repulſion of the overcharged body very great alſo. This can be ſtrictly demonſtrated in ſome very ſimple caſes, but the demonſtration is very tedious: As the reſult, however, is of the firſt importance in the theory of electricity, and ſerves to explain ſome of the moſt abſtruſe phenomena, we wiſh the reader to have ſome ſtronger ground of confidence than the above bare aſſertion. He may obſerve ſimilar effects of cauſes preciſely ſimilar. If we dip the end of a flat ruler into water, and if, after allowing the water to become perfectly ſtill, we move the ruler gently along in a direction perpendicular to the face, we ſhall obſerve a ſingle wave heap up before the ruler, and keep before it, all the reſt of the water before it remaining ſtill: but if we do the ſame thing in a veſſel of clammy fluid, eſpecially if the clammy part is ſwimming on the ſurface of a more perfect fluid, like a cream, we ſhall obſerve a ſeries of ſuch waves to curl up before the ruler, and form before it in ſucceſſion; and if we have previouſly ſpotted the ſurface of the cream, we ſhall ſee that it is not the ſame individual waves that are puſhed before the ruler, but that they are ſucceſſively formed out of different parts of the ſurface, and that the particles which, at one time, form the ſummit of a wave, are, immediately after, at the bottom, &c. In like manner, when a cannon is fired in clear air, at no great diſtance, we hear a ſingle ſnap; but, in a thick fog, we hear the ſnap both preceded and followed by a quivering noiſe, reſembling the ruſhing of a fluttering wind, which laſts perhaps half a ſecond. A ſlight reflection on theſe facts will ſhew that they are neceſſary reſults of the mechanical laws of ſuch obſtruction.

Several neutral points.

The conſequence of this mode of action muſt be, that an imperfect conductor may have more than one neutral point, and more than one overcharged and undercharged portion, ſo that its action on diſtant bodies may be extremely various. The formula of n° 28. was accomodated to this caſe, and will be found to have very curious reſults. Another body may be placed in the direction of the axis, and will be attracted at one diſtance, repelled when this diſtance is increaſed, and again attracted when at a ſtill greater diſtance, &c. &c.

Suppoſe the obſtruction not to be conſiderable: The immediate operation of the neighbouring overcharged body will be the production of an undercharged part in the adjoining extremity, an overcharged part beyond this, an undercharged portion farther on, &c. In a little while theſe will ſhift along the conductor; one after another will diſappear at the farther end, and the body will have at laſt but one neutral point. A greater obſtruction will leave the body, finally, with more than one neutral point, and their ultimate number will be greater in proportion as the obſtruction to the fluid's motion is ſuppoſed greater.

58
Induced electricity rendered permanent.

Now, let the overcharged body, the cauſe of this unequal diſtribution, be removed. We have ſeen, n° 17. that when a body contains its natural quantity of fluid, but unequally diſtributed, there is a force acting on every particle, and tending to reſtore the original equable diſtribution; and that ſuch a force remains as long as there is any inequality in this reſpect. If, therefore, there be no obſtruction, the uniform diſtribution will take place immediately; for it is well known, that the ſpeed with which electricity is propagated is immenſe. The elaſticity, or the attractive and repulſive forces, muſt be very great indeed when compared with any that we know, except, perhaps, the force which impels the particles of light. The electricity, therefore, of a perfect conductor, that is, its power of acting on other bodies in the ſame way that an original electric acts on them, muſt be quite momentary, and ceaſe as ſoon as the inducing cauſe is removed. The conductor is electrical merely in conſequence of its poſition. Hence the propriety of our denominations. Nothing material is ſuppoſed in this theory to be communicated from the overcharged body: Nay, this theory teaches, that the ſenſible electricity of the overcharged body is augmented in ſome reſpects; for it becomes more overcharged in the part neareſt to the conductor. Indeed it becomes leſs overcharged on the other end, and will act leſs forcibly on that ſide than if the conductor were away. It may be remarked here (it ſhould have been mentioned in n° 55.), that when F is preſented in the manner ſhewn in fig. 6. the body B becomes more ſtrongly overcharged at the end remote from A, and more ſtrongly undercharged at the end next to A, than when F is away. The contrary *may* happen, by preſenting a body in the manner of E. We wiſh theſe particulars to be kept in mind. In the mean time, all theſe circumſtances are neceſſary conſequences of the ſuppoſition, that nothing is communicated from A to B or C. The electricity induced on perfect conductors is momentary, requiring the continual preſence of a body that is electrified in ſome way or other.

But the caſe is quite otherwiſe in imperfect conductors. When the overcharged, or otherwiſe electrical body A is removed, the forces which tend to reſtore the uniform diſtribution of the fluid immediately operate and muſt reſtore it in part. They cannot, however, do it completely: For when the force which urges any particle from an overcharged to an undercharged part is juſt in equilibrio with the obſtruction, it will remain, juſt as a number of grains of ſmall ſhot may lie, uniformly mixed with a maſs of clammy fluid, or, as ſuch fluids retain heavy mud, in a ſtate of equable or inequable diffuſion. If the reſiſtance ariſe merely from the inertia of the tangible matter, there is no force ſo ſmall but it will in time reſtore the uniform diſtribution. But this cannot be the caſe in ſolid bodies. Their particles exert lateral forces, by which they maintain themſelves in particular ſituations: theſe muſt be overcome by *ſuperior* forces.

We ſhould therefore expect, that imperfect conductors will retain part of their inequable conſtitution; and, *in conſequence of this*, their power of affecting other bodies like electrics; that is, their ELECTRICITY. For we muſt obſerve (having neglected to do it in the beginning), that the term *electricity* is as often uſed to expreſs this power of producing electrical phenomena as it is uſed for expreſſing a ſubſtance ſuppoſed to be the original cauſe of all theſe appearances. It is neceſſary to keep this diſtinction in mind; becauſe there are many phenomena which clearly indicate the transference of this cauſe, and they muſt not be confounded with others, where the exhibition of electric phenomena is evidently propagated to a diſtance. We muſt not always ſuppoſe, that when the electric appearances are exhibited in an inſtant at the far end of a wire 4½ miles long, the ſame numerical particles of the electric fluid have moved over this ſpace. We muſt diſtinguiſh thoſe caſes where this muſt be granted from thoſe in which it certainly has not happened. Of theſe there are innumerable inſtances.

59
Imperfect conductors are neceſſarily idio-electrics.

We have now to obſerve, that by this theory the ſingle circumſtance of perfect and imperfect conducting power is ſufficient for eſtabliſhing the whole difference between idio-electrics and non-electrics. The idio-electrics are ſuſceptible of excitation in various ways, and retain their electricity; and this may be done in any part of them without affecting the reſt in any remarkable degree. This cannot be done in perfect conductors, plainly *becauſe they are perfect conductors*. Any inequality of diſtribution of the electric fluid, which is all that is neceſſary for rendering them electric, is immediately deſtroyed by its uniform diffuſion. We can have no direct proof of their incapability of excitation; but if they can be excited, they cannot ſhew it. We doubt, however, their excitability; becauſe the appearances in the excitation of electrics ſeem to indicate, that oppoſite ſtates of two bodies are neceſſary previous to the appearance of electricity. This is impoſſible in perfect conductors. By this theory, therefore, perfect conductors are neceſſarily non-electrics; and non-conductors are neceſſarily (if excitable) idio-electrics.

With reſpect to the particular phenomena which may be expected on the removal of the original electric; it may juſt be remarked, that the electric appearances of the imperfect conductor will go off in the contrary order to that of their indication. The accumulation and deficiency will diminiſh gradually, and the neutral point or points will gradually approach the end which had fronted the original electric. The imperfect conductor will be finally left with one or more neutral points, according to the magnitude of the obſtructions, and the force which had been employed in its electrification: And their final ſtate will be ſo much the more inequable, and conſequently they will retain ſo much the greater electric powers, as they are leſs perfect conductors.

60
Electrics are only ſuperficially ſo.

The laſt obſervation which we ſhall make on this head at preſent is, that whether electrified by induction, or by friction, or moſt other modes of excitation, the electirification will be nearly ſuperficial in bodies which conduct very imperfectly; and bodies which are altogether impervious (if there be any ſuch) muſt have the accumulation or deficiency altogether at their ſurface. If a glaſs globe be ſuch a body, it will hardly be poſſible to electrify it to any depth; and all that we can expect is alternate ſtrata of overcharged and undercharged glaſs. If theſe ſtrata are once formed, they tend greatly to make the body retain its ſuperficial electricity. A ſuperficial ſtratum of redundant fluid, tending, by the mutual repulſion of its particles, to eſcape, is retained by the ſtratum of redundant matter immediately below it: And the almoſt inſuperable obſtruction prevents the fluid of the ſtratum beyond this from coming up to ſupply the vacancy. If we can fall on any contrivance to produce ſuch deficient ſtrata within the glaſs, we ſhall make it much more retentive, and capable of holding faſt a much greater quantity. We have already mentioned ſomething of this in nº 14. and we recommend the caſe to the attentive conſideration of the reader.

61
Compariſon of the theory with experiment.

Thus have we given a ſketch of the leading doctrines of this elegant theory of Mr Æpinus, all legitimately deduced from the circumſtances aſſumed in the hypotheſis concerning the *mechanical* properties of that ſubſtance which he calls *the electric fluid*. Let us now ſee with what ſucceſs this hypotheſis may be applied to account for the phenomena. It would have been more philoſophical to have arranged the phenomena, and from the compariſon to have deduced the hypotheſis. But this would have required much more room than can be afforded in a Work like ours.

We preſume, that many of our readers, namely, all ſuch as are already converſant with electrical phenomena and with electric experiments, have ſeen, as we went along, the perfect agreement of the hypotheſis with the various phenomena of attraction and repulſion, and all thoſe which are uſually claſſed under the name of electric atmoſpheres: and we are confident, that when they compare the conſequences that ſhould neceſſarily reſult from ſuch a fluid with the legitimate conſequences of the mechanical action of elaſtic atmoſpheres, they will acknowledge the great ſuperiority of this hypotheſis in point of ſimplicity, perſpicuity, and analogy with other general operations of nature. To ſuch readers it would not be neceſſary to ſtate any farther compariſon; but there are many who have not yet formed any diſtinct *ſyſtematic* view of the appearances called *electrical*. We do not know any way of giving ſuch a view of them as by means of this hypotheſis; and we may venture to ſay, that it will enable the ſtudent of Nature to claſs them all, with hardly a ſingle exception. After which, the hypotheſis may be thrown aſide by the faſtidious philoſopher; and the uſeful claſſification, and general laws of the electric phenomena, will remain ready foundations for a more perfect theory. For the ſake of ſuch readers, therefore, we ſhall take a ſhort review of thoſe general appearances which are accompanied by attractions and repulſions, and compare them with this Æpinian theory.

We ſhall not at preſent conſider the various modes of excitation, although this theory alſo affords much inſtruction on the ſubject, but confine ourſelves entirely to the facts which are moſt immediately dependent on it, and ſhould be employed to ſupport or overturn it; and we ſhall ſuppoſe the reader acquainted with moſt parts of the common apparatus; ſuch as electrometers, inſulation, &c. We alſo preſume that he knows, that when a ſmall pith-ball has been electrified by touching a piece of glaſs which has been excited by rubbing with dry flannel, it will repel another body ſo electrified; and that balls, which have received their electricity in this manner from ſealing-wax excited by the ſame rubber, alſo repel each other; but that balls, thus electrified by glaſs, attract thoſe which are electrified by ſealing-wax.

The following ſimple apparatus will ſerve for all the experiments which are neceſſary for eſtabliſhing the theory:

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Apparatus neceſſary for this compariſon.

1. Two ſlender glaſs rods A (fig. 8.) having a braſs ball B at the end, about a quarter of an inch in diameter, ſuſpending a very ſmall and delicate pith-ball electrometer C.

2. Some electrometers (fig. 9.), conſiſting of two pieces of ruſh pith, about four inches long, nicely ſuſpended, and hanging parallel, and almoſt in contact with each other. It is proper to have them as ſmooth as poſſible, and neatly rounded at the ends, to prevent unneceſſary diſſipation.

3. Some pith-ball electrometers (fig. 10.), whoſe threads are of ſilk, about four inches long, and ſome with flaxen threads moiſtened with a ſolution of ſome deliqueſcent ſalt, that they may be always in a good conducting ſtate.

4. Several braſs conductors (fig. 11.), each ſupported on an inſulating ſtalk and foot. They ſhould be about an inch and half or two inches long, and about three-fourths of an inch in diameter, with round ends, and well poliſhed, to prevent all diſſipation. The foot muſt be ſo narrow as to allow them to touch each other at the ends.

5. Two balls (fig. 12.), one of glaſs, and the other of glaſs coated with ſealing-wax, each furniſhed with an inſulating handle, the other end of which may be occaſionally ſtuck into a foot or into the ſide of a block of wood, which can be ſlid up or down on a wooden pillar, and fixed at any height. Theſe balls ſhould be about three inches in diameter. They muſt be excited by rubbing with dry warm flannel.

6. Some little pieces of gilt card (fig. 13.), about two inches long, half an inch broad, and rounded at the ends, and made as ſmooth as poſſible. Each muſt have a dimple ſtruck in the middle with a poliſhed blunt point, ſo that it will traverſe freely like a mariner's needle, when ſet on a glaſs point, rounded in the flame of a lamp. More artificial needles may be made of ſome light wood, having ſmall cork balls at the ends, all gilt and poliſhed, and turning, in like manner, on glaſs ſtalks: alſo ſome ſimilar needles made of ſealing-wax, one end of each being black, and the other red.

The mechanical phenomena of electricity may be expreſſed in a few ſimple propoſitions. The moſt general fact that we know, and from which all the reſt may be deduced, is the following:

If any body A is electrified, by any means whatever, and if another body B is brought into its neighbourhood, the laſt becomes electrical by poſition.

63 A neutral body attracted, becauſe rendered electrical by induction.

Set the braſs conductors in a row, touching each other, as repreſented in fig. 11. by A, B, C; and let a pith-ball electrometer, having ſilk threads, be ſet near one end of the conductors. Excite one of the globes, by rubbing it with dry flannel. When this is brought near the end of the conductor, the pith-ball will approach the other end. But the globe muſt not be brought ſo near as to cauſe the pith-ball to ſtrike againſt the other end. On removing the globe, the pith-ball will move off and hang perpendicularly. The ſame effect is produced by both globes.

Thus the mere vicinity of the electric renders the conductor electric, and the electricity ceaſes on removing the globe. This is perfectly conformable to the theory, whether we ſuppoſe the fluid to be made redundant or deficient at the remote end of the conductor. If one ſhould aſcribe the approach of the pith-ball to the immediate action of the globe, it is ſufficient to obſerve, that if the ball be ſuſpended near the *ſide* of the conductor, it will approach the conductor, ſhewing that it is affected by the conductor, and not by the globe.

State of diſtribution aſcertained experimentally.

Let the globe be held in the poſition D (fig. 12.), about ſix inches from the conductor, and a little above the line of its axis. Take the glaſs rod (fig. 8.), and bring its knob into contact with the under ſide of the remote end *c* of the conductor. The balls of the electrometer will ſeparate, ſhewing that they are electrified in the ſame manner, and repel each other. Slide the braſs knob along the under ſide of the conductors, quite to the end *a*. The balls will gradually collapſe as the knob approaches a point near the middle of the conductors, where they will hang parallel. Paſſing this point, they will again ſeparate, and moſt of all when the knob is at *a*. In this ſituation they will deviate toward the globe, and will be directed ſtraight toward it, if it be held too near, or in the direction of the axis. This would diſturb the experiment, and muſt be avoided. Theſe phenomena are conformable to the account given of the diſpoſition of the fluid in the conductor. The electrometer may be conſidered as making a part of the conductor; and when its threads hang parallel, it is in its natural ſtate, having its fluid of its natural denſity. This, however, cannot be ſtrictly true, according to the theory; becauſe the balls of the electrometer muſt be conſidered as more remote from the electric, and their electrical ſtate muſt correſpond to a point of the conductor more remote than that where the knob of the electrometer touches it. This will be more remarkably the caſe as the threads are longer. Accordingly, an electrometer with very long threads will never collapſe. The place of the neutral point cannot be accurately aſcertained in this way. Lord Mahon imagined, that its ſituation B was determined (in his experiments with a long conductor) to be ſuch, that D *c* was harmonically divided in B and *a*; and he finds this to be agreeable to the reſult of an electric atmoſphere whoſe denſity is inverſely proportional to the ſquare of the diſtance. But we cannot deduce this from his narration of the experiment. He gives no reaſon for his ſelection of the point D, nor tells us the form and dimenſions of the electric employed, nor takes into account the action of the fluid in the long conductor. It is evident, that no computation can be inſtituted, even on his Lordſhip's principles, till all this be done. We have always found, that the neutral point was farther from the electric, in proportion as the conductor was ſmaller, and when the electricity was ſtronger: and that the differences in this reſpect were ſo very conſiderable, that no dependence could be had on this experiment for determining the law of action. It ſhould be ſo, both according to Lord Mahon's and Mr Æpinus's theory. But to proceed with our examination:

Lord Mahon's determination of the neutral point not warranted by his explanation.

Having touched the end *c* of the conductor with the knob of the electrometer, bring it away. The balls will continue to repel each other, and they are attracted by any body that is in its natural ſtate. Touch the ſame end with the knob of the other electrometer, and bring it alſo away; the balls of the two electrometers will be found to repel each other: but if one has touched the conductor at *c*, and the other has touched it at *a*, the electrometers will ſtrongly attract each other. All this is quite conformable to the theory. If the fluid has been compreſſed at *c*, and therefore the balls of that electrometer are overcharged, they muſt repel each other, and repel any other body electrified in the ſame way. They muſt attract and be attracted by any natural body. But the balls of the other electrometer having touched the conductor at *a*, muſt be undercharged, and the redundant fluid of the one muſt attract the redundant matter of the other.

If the conductor has been electrified by the vicinity of excited glaſs, the electrometer which touched it in the remote end *c*, will be repelled by a piece of excited glaſs, but attracted by excited ſealing-wax. The electrometer which touched the conductor in *a* will be attracted by excited glaſs, and repelled by excited ſealing-wax. The contrary will be obſerved if the conductor has had its electricity induced on it by the vicinity of the globe covered with ſealing-wax. This is a complete proof that Mr Dufuy's doctrine of *vitreous* and *reſinous* electricity is unfounded. Both kinds of electricity are produced in a conducting body, without any material communication, by mere juxta-poſition to a body poſſeſſed of either the vitreous or the reſinous electricity.

64
Conſtant diſtinctions of redundancy and deficiency.

We have not yet mentioned any reaſons which indicate which end of the conductor is electrical by the redundancy of electric fluid, nor is the reader prepared for ſeeing their force. It is generally believed, that the remote end of a conductor which is electrified by glaſs, excited by rubbing it with flannel or amalgamated leather, is electrical by redundancy. No difference has been obſerved in the attractions and repulſions. But there are other marks of diſtinction which are conſtant, and undoubtedly ariſe from a difference in the mode of action of thoſe mechanical forces. If, while the excited glaſs globe remains at D, a glaſs mirror, foiled as uſual with tin leaf, be made to touch the remote end of the conductor, and ſlowly drawn tranſverſely, ſo that the conductor draws a line as it were acroſs it—this mirror being laid down with the foiled ſide undermoſt, the duſt, which ſettles on it in the courſe of a day or two, will be chiefly collected along this line, ſomewhat in the form of the fibres of a feather. But if the conductor was rendered electrical by the globe covered with ſealing-wax, the duſt will be collected along this line in little ſpots like a row of beads. The appearances will be reverſed if the mirror has been paſſed acroſs the end of the conductor which is neareſt to the excited electric. In ſhort, in whatever way the drawing point has been electrified, if it repel a ball which has touched excited glaſs, the line will be feathered; but if it attract ſuch a ball, the line will be ſpotted. There are many ways of making this appearance much more remarkable (ſee Electricity, *Encycl.* Sect. viii. n° 48.) than this; but we have mentioned it on this occaſion, becauſe the circumſtances which occaſion the difference, whatever it is, are the moſt ſimple poſſible. Nothing is communicated; and therefore the effect muſt ariſe from the unnatural ſtate of a ſubſtance or power reſiding in the body. If it be a ſubſtance *ſui generis*, the electric action muſt ariſe from a different diſtribution of this ſubſtance; from a redundancy and deficiency of it in the different portions of the conductor. Without pretending as yet to ſay which is redundant, we ſhall ſuppoſe, with Dr Franklin, that the electricity of excited glaſs is ſo; and we ſhall uſe the words *redundant* and *poſitive* to diſtinguiſh this electricity from the other. This is merely that we may, on many occaſions, conſiderably abbreviate language.

The different electrical ſtates of the different portions of the conductor may be ſeen in another way, which is perhaps more ſimple and unexceptionable than that already narrated. While the globe remains at D, take the two extreme pieces A and C aſide; or, if only two pieces have been uſed, draw the remote piece farther away. Now remove the excited globe. When we examine A ſeparately, we ſhall find it wholly negative, or undercharged, ſtrongly repelling a ball electrified by ſealing-wax, and attracting a ball electrified by glaſs. The other piece C exhibits poſitive electricity, attracting and repelling what A repelled and attracted. If only three pieces of the conductor have been employed, the middle piece B is generally poſitive; but this in a very faint degree.

If all the pieces be again joined, they are void of electricity. If, inſtead of ſuch conductors, a row of metal balls, ſuſpended by ſilk lines, are employed, one of them may generally be found without any ſenſible electricity, when ſeparated from the reſt, having been the neutral part of the row while united.

Theſe very ſimple facts ſhew, as completely as can be wiſhed, that if the electric phenomena depend on a fluid moveable in the pores of the body, the conſtitution given it by Mr Æpinus is adequate to the explanation. We may now venture to aſſert, that every other phenomenon of attraction and repulſion will be found in exact conformity with the legitimate conſequences of this conſtitution of the electric fluid.

65
In the induction of electricity nothing is communicated. Inherent powers are excited.

That nothing is communicated from the electric will appear ſtill more forcibly by the following experiment: Let a conductor be rendered electrical in the way now deſcribed, and touch either extremity of it with the little electrometer, and obſerve attentively the divergency of its threads. Now approach its remote extremity with another conducting body, ſuch as a ſingle piece of thoſe conductors, it will be rendered electrical; as may be diſcovered by a delicate electrometer. Obſerve carefully whether the electrometer in contact with the firſt conductor be affected:—it will generally be found to ſpread its threads wider. It will *certainly* be thus affected if the other conductor be very long and bulky, or touched by the hand; or if, inſtead of this ſecond conductor, we approach the firſt with the extended palm of the hand. As the ſecond conductor was rendered electrical, ſo, undoubtedly, is the hand alſo: and its electrification has not deprived the firſt conductor of any of its electric power, but, on the contrary, has increaſed it. And this augmentation of its power is equally ſenſible at both ends: For an electrometer at the other end will alſo diverge more when the hand is brought near the remote end. This theroy explains this in the moſt ſatisfactory manner. The firſt conductor renders the ſecond electric, by propelling its fluid to a greater diſtance. The ſecond conductor now acts on the fluid that is moveable in the firſt, and cauſes a greater accumulation in its end which is fartheſt from the electric; that is, renders it more electric.

66
The forced diſpoſition of fluid is affected by other electrified bodies.

Suppoſe that, inſtead of employing an excited globe of glaſs, we had made uſe of a conducting body, ſlightly overcharged. Thus if we employ the conductor A, overcharged, to induce electricity on C; this will produce the ſame general effect on our ſet of conductors. But if we have previouſly examined the force of the redundant body, by ſuſpending a pith-ball near it, and obſerving its deviation from the perpendicular, we may ſometimes be led to think, that it has imparted ſomething to the other body. For if the other body and the pith-ball be on oppoſite ſides of the redundant body, the pith-ball will fall a little; indicating a diminution of electric force. But this *ſhould happen* according to the theory; for it was ſhewn, in n° 52. that the conſtipation in the remote end of the overcharged body will be diminiſhed, and along with this, its action on the pith-ball. We ſhould find the electricity of the other end, next the conductor, increaſed, could we find an eaſy way of examining it; but an electrometer applied there will be too much affected by the conductor.

The ſame concluſions may be drawn from the following facts: Hang up a ruſh-pith electrometer. Approach it below with a body ſlightly electrified. The legs of the electrometer immediately diverge, though attracted by the electrified body. Hold the hand above the electrometer, and they will diverge ſtill more; touch the top of it, and they ſpread yet farther. Hold the electrified body (very weakly electrified) above the electrometer, ſo that its legs may diverge a little. Hold the hand above the electrified body; the legs of the electrometer will come nearer each other.

Theſe appearances are obſerved whether the electric be poſitive or negative. We need not take up time in explaining this by the theory, its agreement is ſo obvious.

Electric needles polarity and verticity.

Laſtly, on this head, if, in place of a fixed conductor, we uſe one of the needles of gilt card, ſet on its pivot, and if we then approach it with another conducting body, in the manner repreſented by E and C of fig. 6. we ſhall obſerve that end of the needle to avoid the other body; but if we bring them together, in the manner repreſented by F and B, they will attract each other. The attraction will be greater when the body F is long; and moſt of all when it communicates with the ground. Theſe phenomena are therefore in perfect conformity with the theory; but it may ſometimes happen that E will attract the end of C that is neareſt to A, and E will be electrified poſitively if A be poſitive. This ſeems inconſiſtent with the theory; and, accordingly, it has been adduced by Volta againſt Lord Mahon's account of the electrical ſtate of a conductor in a ſituation ſimilar to that of C. But the theory of Æpinus ſhews the poſſibility of this caſe. When E is very long, or when it is held in the hand, it is rendered *much more* undercharged than the adjacent part of C; and the fluid in the remoter, but not much remoter, part of C is ſtrongly attracted by the copious redundant matter in the near end of E, and is brought back again, and paſſes over into E, in the way to be deſcribed immediately. The caſe is rare, and it will not happen at any conſiderable diſtance from the neutral point of C. If, indeed, E touch the near end of C before A is brought near, the approach of A will cauſe fluid to paſs into E immediately, and C will be left undercharged on the whole.

The reader, who is at all converſant with electrical experiments, will be ſenſible, that theſe experiments are delicate, requiring the greateſt dryneſs of air, and every attention to prevent the diſſipation of electricity during the performance. This, by changing the ſtate of the conductors and electrometers, will frequently occaſion irregularities. The electrometers are moſt apt to change in this reſpect, it being ſcarcely poſſible to make them perfectly ſmooth and free from ſharp angles. It may therefore happen, that when the conductors have affected them *for ſome time*, by the action of the diſturbing electric, the removal of this electric will not cauſe the electrometers to hang perpendicular; they will often be attracted by the conductors, and often repelled; but the intelligent experimenter, aware of theſe circumſtances, will know what allowances to make.

67
Phenomena of imperfect conductors greatly corroborate the theory.

The theory obtains a ſtill more complete ſupport from a compariſon with ſimilar experiments made with imperfect conductors. If, in place of the ſeries A, B, C, of metalline conductors, we employ cylinders of glaſs or ſealing-wax, or even dry wood or marble, and electrometers with ſilk threads in place of the ruſh-pith electrometers, we ſhall find all the appearances to be ſuch as the theory enables us to predict. If, for example, we uſe a ſingle cylinder A of glaſs, we ſhall find that the neighbourhood of the electric D ſcarcely induces any electricity on A. The electrometer will hardly exhibit the ſmalleſt attraction, and its motions will be almoſt entirely ſuch as ariſe from the immediate influence of the electric body D. A cylinder of very dry wood will be more affected by the electric D; and a circumſtance of theoretical importance is very diſtinctly obſerved, namely, the gradual ſhifting of the neutral point. It will be found to advance along the cylinder for a very long while, when every circumſtance is very favourable, the air very dry, and the wood almoſt a nonconductor; and its final ſituation will be found much nearer to the electric than in the braſs conductor. Several inſtructive experiments of this kind may be found in a treatiſe publiſhed in 1783 by Dr Thomas Milner at Maidſtone in Kent, entitled, "Experiments and Obſervations on Electricity." The author does not profeſs to advance any new doctrines, but only to exhibit experiments ſcientifically arranged for forming a ſyſtem. He ſupports the Franklinian ſyſtem as it was generally underſtood at that time; but is much embarraſſed for the explanation of the repulſion of negative electrics. The Æpinian correction of this theory did not offer itſelf to his mind.

68
Irregularities.

We need not go over the ſame ground again with imperfect conductors. It is well known that ſuch bodies are more weakly attracted and repelled; that the balls of an electrometer with linen threads diverge vaſtly more when an electrified body is held below it, than if the threads are ſilken: that ſuch electrometers frequently exhibit very capricious appearances from the ſlow but real progreſs of the electricity along the threads. Theſe anomalies will be better underſtood when we explain the diſſipation of electricity along imperfect conductors.

69
Induced electricity of imperfect conductors is really permanent.

A very eſſential deduction from the theory is, that the electricity induced on an imperfect conductor muſt have ſome permanency. This is fully confirmed by experiment. But the remarkable inſtances of this particular cannot be produced till we be better acquainted with the methods of producing great accumulations of fluid. It is enough to obſerve at preſent, that a permanent electricity may always be obſerved at the junction of the conductors with their inſulating ſtalks. The braſs conductor A ceaſes to be electric as ſoon as the excited globe is removed; but the very top of the glaſs ſtalk on which it is ſupported will ſenſibly affect a delicate electrometer for a long while after. The following

ing pretty experiment ſhews this permanency very diſtinctly. Set one of the ſealing-wax needles on its pivot, and place it between two inſulated metal ſpheres of conſiderable ſize, at ſuch a diſtance from both as not to receive a ſpark. Electrify theſe balls moderately, one of them poſitively, and the other negatively, and keep them thus electrified for ſome hours by renewing their electrification. The needle quickly arranges itſelf in the line adjoining the two ſpheres, juſt as a magnetic needle will do when placed between two magnets whoſe diſſimilar poles front each other. Any gentle force will derange the needle; but it will vibrate like a magnetic needle, and finally ſettle in its former poſition. When this has been continued ſome time, that end of the needle which pointed to the poſitive globe will be found negative, and the other will be found poſitive, if examined with an electroſcope. And now, if the two globes be removed, this little needle will remain electrical for entire days in dry froſty weather, and its ends will approach any body that is brought near it (taking care not to come too cloſe); and the end which pointed to the poſitive globe will avoid a piece of rubbed ſealing-wax, but will approach a piece of rubbed glaſs; but the other end will be affected in the oppoſite way. In ſhort, it proves an electric needle with a poſitive and negative pole.

If two ſmall inſulated balls are moderately electrified, and placed about ſix inches aſunder, this needle, when carried round them, will arrange itſelf exactly as a magnetic needle does when carried round a magnet of the ſame length. If the ſame trial be made with the needle of gilt card, it will arrange itſelf in the ſame manner that a ſoft iron needle arranges itſelf near a magnet, but either end will turn indifferently to either globe.

Electrical meridians.

If a thin glaſs plate, coated with red ſealing-wax, be ſet on the poſitive and negative globes, and we ſprinkle (from a conſiderable height) a fine powder of black ſealing-wax, and then pat the plate gently with a glaſs rod ſo as to agitate it a little, the particles of wax powder will gradually arrange themſelves into curve lines, diverging from the point over one of the globes, and converging to the point over the other, preciſely like the curves formed by iron-filings ſprinkled on a paper held over a magnet. Each little rag of wax becomes electrical by poſition, acquires two poles, and the poſitive pole of one attracts the negative pole of another; and they adhere in a certain determinate poſition, nearly a tangent to the curve, which was mentioned in nº 50, and indicates the law of magnetic action. When in this ſtate, if a hot brick be held over the plate till the wax ſoften a little, the particles of black wax will adhere to the red coating, and give us a permanent ſpecimen of the action.

70

It is well known that liquid ſealing-wax is a conductor. The writer of this article filled a glaſs tube with powdered ſealing-wax, and melted it, and then expoſed it, in its melted ſtate, to the influence of a poſitive and a negative globe, hoping to make a powerful and permanent electric needle, which ſhould have two poles, and exhibit a ſet of phenomena reſembling thoſe of magnetiſm. Accordingly he, in ſome meaſure, ſucceeded, by keeping the globes continually electrified for ſeveral hours, till the wax was quite cold. It had two diſtinct poles, and preſerved this property, *even though plunged in water, and while immerſed in the water*; but he was greatly diſappointed as to the degree of its electricity. It juſt affected a ſenſible electrometer at the diſtance of ſix inches from either pole. It was conſiderably ſtronger than if it had not been melted during the impregnation, but by no means in the degree that he expected. It retained ſome electricity for about ſix weeks, although lying neglected among conducting bodies. After its power ſeemed quite extinct, he was melting it again in order to renew it. Some light fibrous things chanced to be near it. While it was ſoftening, it became very ſenſibly electrical, cauſing theſe fibres to bend towards it, and even to cling to the tube. We ſhall ſee by and bye, that he was miſtaken in expecting more remarkable appearances, and that the theory, when properly applied, does not promiſe them. Having thus eſtabliſhed (as we think) this theory on ſufficient foundations for making it a very perſpicuous way of explaining the phenomena of induced electricity, we proceed to compare it with the ſecond general fact in electricity.

71 Electricity by communication.

PROP. II. When an inſulated body B is brought very near an electrified body A, a ſpark is obſerved to paſs between them, accompanied with a noiſe (which we ſhall call the electric SNAP), and B is now electrified permanently, and the electricity of A is diminiſhed.

Although this be one of the moſt familiar facts in electricity, it will be proper to conſider its attending circumſtances in a way that connects it with what we have now learned concerning electricity by poſition.

Let the inſulated body A (fig. 14.) be furniſhed with a cork-ball, hanging by a ſilk thread from a glaſs ſtalk connected with A; let B be fitted up in the ſame manner; let A be electrified weakly, and its degree of electricity be eſtimated by the inclination of the ball *towards* A: ſince B is not electrified, its electrometer will hang perpendicular; but when it approaches A (keeping the electrometers on the remote ſides of both), its electrometer will approach it, and the electrometer of A will gradually approach the perpendicular. When the bodies are brought very near, a ſpark is ſeen between them; and, at that inſtant, the electrometer of B comes much nearer to it, and that of A drops farther from it. If they be now ſeparated, their electrometers will retain their new poſitions with very little change, and B will now manifeſt the ſame kind of electricity with A.

Such is the appearance when A has been but weakly electrified. Bringing B near A, the fluid in B is drawn to the remote ſide, if A be overcharged, or drawn to the ſide neareſt to A, if A has been undercharged. B acts on its electrometer in conſequence of the change made in the diſpoſition of its fluid. The electrometer is attracted. In the mean time, the change made in the diſpoſition of the fluid in B affects the moveable fluid in A. If A was overcharged, the ajacent ſide of B becomes undercharged, and its redundant matter, attracting the fluid in A, condenſes it in the adjacent ſide, abſtracting part of the redundant fluid from that ſide which is next to the pith-ball. Then the joint action of the whole redundant fluid in A on the pith-ball is diminiſhed.

Muſt happen abruptly.

As there is now an attraction in the redundant fluid in A for the redundant matter on the adjacent ſide of B,

76
Inſulation neceſſary for electric appearances.

3. If an electrified conducting body touch any thing communicating with the ground by perfect conductors, all its electricity muſt diſappear, and none can appear in the body touched by it; for the maſs of the earth bears ſuch an unmeaſurable proportion to that of the greateſt body that we can electrify, that when the redundancy or deficiency is divided between them, it muſt be imperceptible in both.

77

Hence the neceſſity of *inſulation*, as it is called, or the ſurrounding by non-conductors every body which we would have exhibit electric appearances. We muſt refer the reader to the article Electricity in the *Encycl.* for all the obſervations on this head, and the reaſons of preference given to certain ſubſtances to be employed for inſulating ſupports. But we muſt conſider, in its proper place, the manner in which the electric fluid is diſſipated by imperfectly inſulating ſubſtances; a ſubject intimately connected with the theory.

78
An electri-
ied body
ttracts and
hen repels
ny unelec-
rified bo-
y.

4. Any unelectrified body will be firſt attracted by an electrified body, will touch it, and will then be repelled. The neutral body is rendered electrical by induction. It is, *in conſequence of this*, attracted, comes near enough to receive a ſpark, or even touches it, and is then electrified by communication; and, *in conſequence of this*, it is repelled. This is confirmed by an endleſs train of experiments. It was firſt taken notice of (we think) by Sir Iſaac Newton. Otho Guericke, a gentleman of Magdeburgh, to whom we owe the air pump, mentions many inſtances of the repulſion, but did not obſerve that it was an univerſal law. Newton was ſo ſtruck with it as to engage in a conſiderable train of experiments in the early part of his life, while meditating on the power of gravity; but even his ſagacious mind did not obſerve the whole proceſs of nature in his experiments. He obſerved, that the light bodies which roſe and adhered to the rubbed plate of glaſs were ſoon after repelled by it; but did not obſerve, that the ſame piece would again riſe to the glaſs after it had touched the table. This fact is now the foundation of many experiments, which the itinerant electricians vie with each other in rendering very amuſing. We may render them inſtructive. Take away the middle conductor B (fig. 11.), and hang in its place a cork ball by a long ſilk thread. As ſoon as the electric body D is brought near to A, the ball is attracted by its remote end, comes into contact, is repelled by it, and attracted by the adjacent end of C, touches it, is faintly repelled by it, and again attracted by A; and the operation is repeated ſeveral times. When all has ceaſed, remove C, and alſo the electric D. C is found to have the ſame electricity with D, and A has the oppoſite electricity. The proceſs is too obvious to need any detailed application of the theory. The cork ball was the carrier of fluid from A to C if D was electric by redundancy, or from C to A if D was undercharged. If inſtead of removing C when the vibrations of the ball have ceaſed, we bring D a little nearer, they will be renewed, and, after ſome time, will again ceaſe. The reaſon is plain. The carrier ball had brought the conductor A into a ſtate of equilibrium with the action of D. But this action is now increaſed, and the effects are renewed. If we now remove D, the ball will vibrate between A and C with great rapidity for a conſiderable time before the vibrations come to an end; and we ſhall find their number to be the ſame as before. The cauſe of this is alſo obvious from the theory. We may ſuppoſe A to be negative, and C poſitive. One of them will attract the ball into contact, and will repel it, having put it into an electric ſtate oppoſite to that of the other conductor. It now becomes a carrier of fluid from the poſitive to the negative conductor, till it nearly reſtore both to their primitive ſtate of neutrality.

79
Irregularities frequent—Why.

There is frequently a ſeeming capricioufneſs in thoſe attractions and repulſions. A pith ball, or a down feather, hung by ſilk, will cling to the conductor, or otherwiſe electrified body, and will not fly off again, at leaſt for a long while. This only happens when thoſe bodies are ſo dry as to be almoſt non-conductors. They acquire a poſitive and negative pole, like an iron nail adhering to a magnet, and are not repelled till they become almoſt wholly poſitive or negative. It never happens with conducting light bodies.

80
Electric action, like gravitation, is not hindered by the interpoſition of non-conductors.

5. It ſhould follow from the theory, that the electric attractions and repulſions will not be prevented by the intervention of non-conducting ſubſtances in their neutral ſtate. Accordingly, it is a fact, that the interpoſition of a thin pane of glaſs, let it be ever ſo extenſive, does not hinder the electrometer from being affected. Alſo, if an inſulated electric be covered with a glaſs bell, an electrometer on the outſide will be affected. Nay, a metal ball, covered to any thickneſs with ſealing-wax, when electrified, will affect an electrometer in the ſame way as when naked. We cannot ſee how theſe facts can be explained by the action of electric atmoſpheres. It is indeed ſaid, that the atmoſphere on one ſide of the glaſs produces an atmoſphere on the other; but we have no explanation of this production. If the interpoſed plate be a non-conductor, how does the one atmoſphere produce the other? It muſt produce this effect by acting at a diſtance on the particles which are to form this atmoſphere. Of what uſe, then, is the atmoſphere, even if thoſe atmoſpheres could effect the obſerved motions of the electrometer in conſiſtency with the laws of mechanics? The atmoſpheres only ſubſtitute millions of attractions or repulſions in place of one. We muſt obſerve, however, that the motions of the electrometer are modified, and ſometimes greatly changed, by the interpoſed non-conducting plate; but this is owing to the electricity induced on the plate. If the electric is poſitive, the adjacent ſurface of the plate becomes faintly negative, and the ſide next the electrometer ſlightly poſitive. This affects the electrometer even more than the more remote electric does. That this is the cauſe of the difference between the ſtate of the electrometer when the plate is there and when it is removed, will appear plainly by breathing gently on the glaſs plate to damp it, and give it a ſmall conducting power. This will make ſome change in the poſition of the electrometer. Continue this more and more, till the plate will no longer inſulate. The changes produced on the electrometer's poſition will form a regular ſeries, till it is ſeen to aſſume the very poſition which it would have taken had the plate been braſs. Then, conſidering thoſe changes in a contrary order, and ſuppoſing the ſeries continued a little farther, we ſhall always find that it leads to the poſition which it would have taken when no plate whatever is interpoſed. We conſider this as an important fact, ſhewing that the electric action is ſimilar to gravitation, and that there is

B, it is reaſonable to ſuppoſe, that when this attraction, joined to the repulſion of the redundant fluid behind it, is able to overcome the attraction which connects it with the ſuperficial particles of the matter, it will then eſcape and fly into B: but this will not happen gradually, but at once, as ſoon as the expelling force has ariſen to a very conſiderable intenſity. We cannot ſay what is the preciſe augmentation that is neceſſary; but we can clearly ſee, that however great the attraction for the adjoining particles may be, while the particle is ſurrounded by them on *all* ſides, it will yield to the ſmalleſt inequality of force, becauſe the particles before it attract as much as thoſe behind it; but when it is juſt about to quit the laſt or ſuperficial particles of A, a much greater force is now neceſſary. It can be ſtrictly demonſtrated, that when the mutual tendency is inverſely as the ſquare of the diſtance, the action of a particle placed immediately without a ſphere of ſuch matter is double of its action when ſituated in the very ſurface*. A *ſaltus* of this kind muſt obtain whatever be the law of electric attraction. We ſhall ſee other cauſes alſo which ſhould prevent the eſcape of redundant fluid, and alſo its admiſſion, till the impelling force is encreaſed in a certain abrupt degree.

72 Theſe obſervations muſt ſuffice at preſent to explain the deſultory nature of this transference, if there be really a transference. That this has happened, may be confidently inferred from the ſudden diminution of the electricity of A, indicated by the ſudden fall of its electrometer; but it is more expreſsly eſtabliſhed, that there has been a transference by the change produced on B. It is now permanently electrified, and its electricity is of the ſame kind with that of A, poſitive or negative according as A is poſitive or negative. And now we are enabled to explain the third general fact in electricity.

73 Imparted electricity produces mutual repulſion.

Prop. III. When a body has imparted electricity to another, it conſtantly repels it, unleſs that other has afterwards imparted all its electricity to other bodies. This fact, from which there is no exception, is an immediate conſequence of the theory. Before the transference ſuppoſed by it, B was in its natural ſtate; after the transference, both bodies contain redundant fluid, or redundant matter; therefore they muſt mutually repel.

We may now take another form of the experiment, which will be much more convincing and inſtructive. Let A be electrified poſitively, or by redundancy, and let its electrometer be attached to it by a conducting ſtalk, and have a flaxen thread; let this be the caſe alſo with the electrometer of B; then the appearances ſhould happen in the following order: When A is made to approach B, the electrometer of B muſt gradually riſe, diverging *from* B; becauſe the fluid condenſed on the ſide remote from A, and in the electrometer, will act more ſtrongly on it than the deſerted matter on the other ſide of B; and when the ſudden transference is made, and B is wholly overcharged, its electrometer will immediately riſe much higher, and muſt remain at that height, nearly, when A is removed. On the other hand, the electrometer attached to the remote ſide of A muſt deſcend, by reaſon of the change made in the diſpoſition of the fluid in A by the induced electrical ſtate of B: and when a conſiderable portion of the redundant fluid in A paſſes into B, the electrometer of A muſt ſuddenly ſink much lower, and remain in that ſtate when B is removed.

Transference of a peculiar ſubſtance highly pr bable.

Many circumſtances of this phenomenon corroborate our belief of a real transference of matter. The cauſe of electric action reſided formerly in A alone; it now reſides alſo in B. The larger that B is, the greater is the diminution of A's electric power, and the ſmaller is the power acquired by B. It perfectly reſembles, in this reſpect, the communication of ſaltneſs, ſweetneſs, &c. by mixing a ſolution of ſalt or ſugar with different quantities of water; and the evidence of a transference of a ſubſtance, the cauſe of electric attractions and repulſions, is at leaſt as cogent as the evidence of the transference of heat, when we mix hot water with a quantity of cold, or when a hot ſolid body is applied to the ſide of a cold one. We alſo ſee ſo many chemical and other changes produced by this communication of electricity, that we can hardly refuſe admitting that *ſome material ſubſtance* paſſes from one body to another, and, in its new ſituation, exerts its attractions and repulſions, and produces all their effects.

We may deduce the following corollaries; all of which are exactly conformable to the phenomena, ſerving ſtill more to confirm the juſtneſs of the theory.

74 Degree vivacit propor ed to t quanti impart

1. A certain quantity of what poſſeſſes theſe powers of attraction and repulſion is neceſſary for giving a determined vivacity to the appearances. Another ſpark muſt paſs between the bodies, *only if they be brought ſtill nearer*, and their electrometers muſt riſe and fall ſtill farther. For by the firſt transference of electric fluid into B, the expelling power of A is diminiſhed, and the ſuperior attraction of the redundant matter in the adjacent ſide of B is alſo counteracted by the repulſion of the fluid which has entered into it; therefore no more will follow unleſs theſe forces be encreaſed, at leaſt to their former degree. When this addition has been made to B, and this abſtraction from A, their reſpective electrometers muſt be affected. All this is in perfect conformity to experience.

7 Comn catio rema in co tors.

2. All the phenomena of communicated electricity muſt be more remarkable in proportion to the conducting power of the bodies. A very imperfect conductor, ſuch as glaſs or ſealing-wax, will impart or receive fluid only between the very neareſt parts; whereas a metalline body is inſtantly affected through its whole extent. This deduction is perfectly agreeable to the whole train of electric experiments. The finger receives a ſtrong ſpark from a large metalline electrified body, which diſcharges *every part of it* of a portion of its electricity. But an excited globe, which ſhews, by its action on a diſtant body, as great a degree of electricity, will give only a very ſmall ſpark; and it is found not to be affected at any conſiderable diſtance from the point of its ſurface from which the transference was made. The whole electricity of a perfect conductor is diſcharged by touching it; but a nonconductor will ſucceſſively give ſparks, if touched in many different parts; and it may be ſeen by a nice electrometer, that each contact takes away the electricity only from a very ſmall ſpace round it: and it is further highly deſerving of notice, that ſome time after a ſpark has been obtained from a particular ſpot of the electric, a ſecond ſpark may be obtained from it, the electricity of the neighbouring parts having been gradually diffuſed through it.

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* *Opuſcles. de d'Alembert*, T. I. 257.

76 Inſulation neceſſary for electric appearances.

3. If an electrified conducting body touch any thing communicating with the ground by perfect conductors, all its electricity muſt diſappear, and none can appear in the body touched by it; for the maſs of the earth bears ſuch an unmeaſurable proportion to that of the greateſt body that we can electrify, that when the redundancy or deficiency is divided between them, it muſt be imperceptible in both.

77 Hence the neceſſity of *inſulation*, as it is called, or the ſurrounding by non-conductors every body which we would have exhibit electric appearances. We muſt refer the reader to the article Electricity in the *Encycl.* for all the obſervations on this head, and the reaſons of preference given to certain ſubſtances to be employed for inſulating ſupports. But we muſt conſider, in its proper place, the manner in which the electric fluid is diſſipated by imperfectly inſulating ſubſtances; a ſubject intimately connected with the theory.

78 An electrified body attracts and then repels any unelectrified body.

4. Any unelectrified body will be firſt attracted by an electrified body, will touch it, and will then be repelled. The neutral body is rendered electrical by induction. It is, *in conſequence of this*, attracted, comes near enough to receive a ſpark, or even touches it, and is then electrified by communication; and, *in conſequence of this*, it is repelled. This is confirmed by an endleſs train of experiments. It was firſt taken notice of (we think) by Sir Iſaac Newton. Otho Guericke, a gentleman of Magdeburgh, to whom we owe the air pump, mentions many inſtances of the repulſion, but did not obſerve that it was an univerſal law. Newton was ſo ſtruck with it as to engage in a conſiderable train of experiments in the early part of his life, while meditating on the power of gravity; but even his ſagacious mind did not obſerve the whole proceſs of nature in his experiments. He obſerved, that the light bodies which roſe and adhered to the rubbed plate of glaſs were ſoon after repelled by it; but did not obſerve, that the ſame piece would again riſe to the glaſs after it had touched the table. This fact is now the foundation of many experiments, which the itinerant electricians vie with each other in rendering very amuſing. We may render them inſtructive. Take away the middle conductor B (fig. 11.), and hang in its place a cork ball by a long ſilk thread. As ſoon as the electric body D is brought near to A, the ball is attracted by its remote end, comes into contact, is repelled by it, and attracted by the adjacent end of C, touches it, is faintly repelled by it, and again attracted by A; and the operation is repeated ſeveral times. When all has ceaſed, remove C, and alſo the electric D. C is found to have the ſame electricity with D, and A has the oppoſite electricity. The proceſs is too obvious to need any detailed application of the theory. The cork ball was the carrier of fluid from A to C if D was electric by redundancy, or from C to A if D was undercharged. If inſtead of removing C when the vibrations of the ball have ceaſed, we bring D a little nearer, they will be renewed, and, after ſome time, will again ceaſe. The reaſon is plain. The carrier ball had brought the conductor A into a ſtate of equilibrium with the action of D. But this action is now increaſed, and the effects are renewed. If we now remove D, the ball will vibrate between A and C with great rapidity for a conſiderable time before the vibrations come to an end; and we ſhall find their number to be the ſame as before. The cauſe of this is alſo abvious from the theory. We may ſuppoſe A to be negative, and C poſitive. One of them will attract the ball into contact, and will repel it, having put it into an electric ſtate oppoſite to that of the other conductor. It now becomes a carrier of fluid from the poſitive to the negative conductor, till it nearly reſtore both to their primitive ſtate of neutrality.

79 Irregularities frequent—Why.

There is frequently a ſeeming capriciouſneſs in thoſe attractions and repulſions. A pith ball, or a down feather, hung by ſilk, will cling to the conductor, or otherwiſe electrified body, and will not fly off again, at leaſt for a long while. This only happens when thoſe bodies are ſo dry as to be almoſt non-conductors. They acquire a poſitive and negative pole, like an iron nail adhering to a magnet, and are not repelled till they become almoſt wholly poſitive or negative. It never happens with conducting light bodies.

80 Electric action, like gravitation, is not hindered by the interpoſition of non-conductors.

5. It ſhould follow from the theory, that the electric attractions and repulſions will not be prevented by the intervention of non-conducting ſubſtances in their neutral ſtate. Accordingly, it is a fact, that the interpoſition of a thin pane of glaſs, let it be ever ſo extenſive, does not hinder the electrometer from being affected. Alſo, if an inſulated electric be covered with a glaſs bell, an electrometer on the outſide will be affected. Nay, a metal ball, covered to any thickneſs with ſealing-wax, when electrified, will affect an electrometer in the ſame way as when naked. We cannot ſee how theſe facts can be explained by the action of electric atmoſpheres. It is indeed ſaid, that the atmoſphere on one ſide of the glaſs produces an atmoſphere on the other; but we have no explanation of this production. If the interpoſed plate be a non-conductor, how does the one atmoſphere produce the other? It muſt produce this effect by acting at a diſtance on the particles which are to form this atmoſphere. Of what uſe, then, is the atmoſphere, even if thoſe atmoſpheres could effect the obſerved motions of the electrometer in conſiſtency with the laws of mechanics? The atmoſpheres only ſubſtitute millions of attractions or repulſions in place of one. We muſt obſerve, however, that the motions of the electrometer are modified, and ſometimes greatly changed, by the interpoſed non-conducting plate; but this is owing to the electricity induced on the plate. If the electric is poſitive, the adjacent ſurface of the plate becomes faintly negative, and the ſide next the electrometer ſlightly poſitive. This affects the electrometer even more than the more remote electric does. That this is the cauſe of the difference between the ſtate of the electrometer when the plate is there and when it is removed, will appear plainly by breathing gently on the glaſs plate to damp it, and give it a ſmall conducting power. This will make ſome change in the poſition of the electrometer. Continue this more and more, till the plate will no longer inſulate. The changes produced on the electrometer's poſition will form a regular ſeries, till it is ſeen to aſſume the very poſition which it would have taken had the plate been braſs. Then, conſidering thoſe changes in a contrary order, and ſuppoſing the ſeries continued a little farther, we ſhall always find that it leads to the poſition which it would have taken when no plate whatever is interpoſed. We conſider this as an important fact, ſhewing that the electric action is ſimilar to gravitation, and that there

Chemical effects.

3. The ſpark produces ſome very remarkable chemical effects. It calcines metals even under water or oil; it renders Bolognian phoſphorus luminous: It decompoſes water, and makes new compoſitions and decompoſitions of many gaziform fluids; it affects vegetable colours; it blackens the calces of biſmuth, lead, tin, luna cornea; it communicates a very peculiar ſmell to the air of a room, which is diſtinct from all others; and in the calcination of metals, it changes remarkably the ſmells with which this operation is uſually accompanied: it affects the tongue with an acidulous taſte; it agitates the nervous ſyſtem.—When we compare theſe appearances with ſimilar chemical and phyſiological phenomena, which naturaliſts never heſitate in aſcribing to the action of material ſubſtances, transferable from one body, or one ſtate of combination, to another, we can ſee no greater reaſon for heſitating in aſcribing the electric phenomena to the action of a material ſubſtance; which we may call *a fluid*, on account of its connected mobility, and *the electric fluid*, on account of its diſtinguiſhing effects. We are well aware, that theſe evidences do not amount to demonſtration; and that it is poſſible that the electric phenomena, as well as many chemical changes, may reſult from the mere difference of arrangement, or poſition, of the ultimate particles of bodies, and may be conſidered as the reſult of a change of modes, and not of things. But in the inſtances we have mentioned, this is extremely improbable.

This is therefore aſſumed.

We therefore venture to aſſume the exiſtence of this ſubſtance, which philoſophers have called *the electric fluid*, as a propoſition abundantly demonſtrated; and to affirm, on the authority of all the above-mentioned facts, that its mechanical character is ſuch as is expreſſed in Mr Æpinus's hypotheſis.

We proceed, therefore, to explain the moſt intereſting phenomena of electricity from theſe principles.

84
Diſtribution of it depends on its law of action.

We have ſeen that, in a perfect conductor, in its natural ſtate, the electric fluid is uniformly diſtributed, and cannot remain in any other condition. We are particularly intereſted to know how it is diſtributed in an overcharged or undercharged body, and how this is affected by the circumambient non-conducting air. It is evident that much depends on this. The tendency to eſcape, and, particularly, the tendency to transference from one body to another, muſt be greateſt where the fluid is moſt conſtipated. We know that it tends remarkably to diſſipate from all protuberances, edges, and long bodies, and that it is impoſſible to confine it in a body having very acute far-projecting points; and, what is more paradoxical, it is hardly poſſible to prevent its entering into a body furniſhed with a ſharp point. The ſmalleſt reflection muſt ſuggeſt to our imagination, that a perfectly moveable fluid, whoſe particles mutually repel, even at conſiderable diſtances, and which is confined in a veſſel from which it cannot eſcape, muſt be compreſſed againſt the ſides of the veſſel, and be denſer there than in the middle of the veſſel. But in what proportion its denſity will diminiſh as we recede from the walls of the veſſel, muſt depend on the change of electric repulſion by an increaſe of diſtance. The intenſity varies in the proportion of ſome function of the diſtance, and may be expreſſed by the ordinates of a curve, on whoſe axis the diſtances are meaſured. But we are ignorant of this function. We muſt therefore endeavour to diſcover it, by obſerving a proper ſolution of phenomena. Having made ſome approximation to this diſcovery, ſuch as ſhall give riſe to a *probable conjecture* concerning the function which expreſſes the intenſity of electric repulſion, mathematics will then enable us to ſay how the fluid muſt be diſtributed (at leaſt in ſome ſimple and inſtructive caſes) in a perfectly conducting body ſurrounded by the air, and what will be its action on another body. Thus we ſhall obtain oſtenſible reſults, which we can compare with experiments. The writer of this article made many experiments with this view above 30 years ago, and flatters himſelf that he has not been unſucceſsful in his attempts. Theſe were conducted in the moſt obvious and ſimple manner, ſuggeſted by the reaſonings of Mr Æpinus; and it was with ſingular pleaſure that, ſome years after, he peruſed the excellent diſſertation of Mr Cavendiſh in the Philoſophical Tranſactions, vol. 61. where he obtained a much fuller conviction of the truth of the concluſion which he had drawn, in a ruder way, from more familiar appearances. Mr Cavendiſh has, with ſingular ſagacity and addreſs, employed his mathematical knowledge in a way that opened the road to a much farther and more ſcientific proſecution of the diſcovery, if it can be called by that name. After this, Mr Coulomb, a diſtinguiſhed member of the French academy of ſciences, engaged in the ſame reſearch in a way ſtill more refined; and ſupported his concluſions by ſome of the moſt valuble experiments that have been offered to the public. We ſhall now give a very brief account of this argument: and have premiſed theſe hiſtorical remarks; becauſe the writer, although he had eſtabliſhed the general concluſion, and had read an account of his inveſtigation in a public ſociety in 1769, in which it was applied to the moſt remarkable facts then known in electricity, has no claim to the more elaborate proofs of the ſame doctrine, which is given in ſome of the following paragraphs. Theſe are but an application of Mr Cavendiſh's more cautious and general mathematical procedure, to the function which the writer apprehends to be ſufficiently eſtabliſhed by obſervation.

Proceſs for diſcovering this law.

The moſt unexceptionable experiments with which we can begin, ſeem to be the repulſions obſervable between two *ſmall* ſpheres. Whatever be the law of diſtribution of the particles in a ſphere, the general action of its particles on the particles of another ſphere will follow a law which will not differ much from the law of action between two particles, if the diameters of the ſpheres be ſmall in proportion to their diſtance from each other. The inveſtigation was therefore begun with them. But the ſubject required an electrometer ſuſceptible of compariſon with others, and that could exhibit abſolute meaſures. The one employed was made in the following manner; and we give it to the public as a valuable philoſophical inſtrument.

85
Comparable electrometer.

Fig. 15. repreſents the electrometer in front. A is a poliſhed braſs ball, $\frac{1}{4}$th of an inch in diameter. It is fixed on the point of a needle three inches long, as ſlender as can be had of that length. The other end of the needle paſſes through a ball of amber or glaſs, or other firm non-conducting ſubſtance, about half or three-fourths of an inch in diameter; but the end muſt not reach quite to the ſurface, although the ball is completely perforated. From this ball riſes a ſlender glaſs rod FEL, three inches long from F to E, where it bends

4. This tendency is proportional to the denſity and thickneſs of the plate or plates jointly.

It is only in two or three ſimple caſes that we can propoſe to ſtate with preciſion what will be the diſpoſition and action of the electric fluid in bodies; but we ſhall ſelect thoſe that are moſt inſtructive, and connected with the moſt remarkable and important phenomena.

92 Diſpoſition in parallel plates. Let A *a d* D (fig. 18.) and E *e h* H repreſent the ſections of a part of two infinitely extended parallel plates (which we ſhall call A and E), conſiſting of ſolid conducting matter, in which the electric fluid can move without any obſtruction, but from which it cannot eſcape.

When both are overcharged, *Firſt*, Let them be both overcharged, A containing the quantity *r* of redundant fluid, and E containing the quantity *s*, and let *r* be greater than *s*.

The fluid will be diſpoſed in the following manner:

1. There will be two ſtrata, A *a b* B and G *g h* H, adjoining to the remote ſurfaces, in each of which the quantity $\frac{r+s}{2}$ will be crowded together as cloſe as poſſible.

2. Adjoining to the interior ſurface (that is, the ſurface neareſt to E) of the plate A, there will be a ſtratum C *c d* D, containing the quantity $\frac{r-s}{2}$ crowded together.

3. The adjacent ſide of E will have a ſtratum E *e f* F, juſt ſufficient for containing the quantity $\frac{r-s}{2}$ at its natural denſity. This ſtratum will be entirely exhauſted of fluid.

4. The ſpaces B *b c* C and F *f g* G will be in their natural ſtate.

For a particle of fluid in the ſpace B *b c* C is urged in the direction *a d* by the force $\frac{r+s}{2}$ (n° 91, 3.), and in the direction *d a* by the force $\frac{r-s}{2}$, therefore it is, on the whole, urged in the direction *a d* with the force *s*, which will balance the repulſion of the redundant fluid in the other plate. A particle of fluid in the ſpace F *f g* G is repelled in the direction *h e* by a force $\frac{r+s}{2}$ by the fluid in G *g h* H, and it is attracted in the ſame direction by the redundant matter in E *e f* F, with the force $\frac{r-s}{2}$. Theſe make a force *r* which balances the repulſion *r* of the other plate. No other diſpoſition will be permanent; for if a particle be taken out from either ſtratum A *a b* B or C *c d* D into the ſpace between them, the repulſion from that ſtratum which it quitted is leſſened, and the repulſion of the oppoſite ſtratum, joined to that of the other plate, will drive it back again. The ſame thing holds with reſpect to the fluid in the other plate.

93 *Cor.* 1. If the two plates be equally overcharged, all the redundant fluid will be crowded on the remote ſurfaces, and the adjacent ſurfaces will be in the natural ſtate.

94 When they are undercharged, In the *ſecond* place, let the plates be undercharged, and let *r* be the fluid wanting in A, and *s* the fluid wanting in E, and let *s* be greater than *r*; then,

1. The ſtrata adjoining to A *a* and H *h* will be completely exhauſted of fluid, and the redundant matter in each will be ſuch as would be ſaturated by $\frac{r+s}{2}$.

2. The ſtratum C *c d* D will contain redundant fluid $\frac{s-r}{2}$, crowded cloſe.

3. The ſtratum E *e f* F will be deprived of fluid, and the quantity abſtracted is $\frac{s-r}{2}$.

4. The ſpaces B *b c* C and F *f g* G are in the natural ſtate.

The demonſtration is the ſame as in the former caſe.

95 When they are in oppoſite ſtates *Thirdly*, Let A be overcharged, and E undercharged, A containing the redundant fluid *r*, and E wanting the fluid *s*; and let *r* be greater than *s*. Then,

1. The ſtrata A *a b* B and G *g h* H contain the redundant fluid $\frac{r-s}{2}$, crowded cloſe.

2. The ſtratum C *c d* D contains the quantity $\frac{r+s}{2}$, crowded cloſe.

3. The ſtratum E *e f* F is exhauſted, and wants the quantity $\frac{r+s}{2}$.

4. The reſt is in the natural ſtate.

96 *Cor.* 2. If the redundant fluid in A be juſt ſufficient to ſaturate the redundant matter in E, the two remote ſurfaces will be in their natural ſtate, all the redundant fluid in A being crowded into the ſtratum C *c d* D, and all the redundant matter being in E *e f* F.

This diſpoſition will be the ſame, whatever is the diſtance or thickneſs of the plates, unleſs the redundant fluid in A be more than can be contained in the whole of E when crowded cloſe.

97 Preſſure and tendency to eſcape. When the two plates are overcharged, the fluid preſſes their remote ſurfaces with the force $\frac{\overline{r+s}^2}{4}$, and would eſcape with that force if a paſſage were opened. It would enter the remote ſurfaces of two undercharged plates with the ſame force; and, in either caſe, it would run from the inner ſurface of one to the adjacent ſurface of the other, with the force $\frac{\overline{r-s}^2}{4}$.

If one be overcharged and the other undercharged, fluid would eſcape from the remote ſurface with the force $\frac{\overline{r-s}^2}{4}$, and would run through a canal between them with the force $\frac{\overline{r+s}^2}{4}$.

Mutual actions. They repel or attract each other with the force $\overline{r+s}^2$, according as they are both over or undercharged, or as one is overcharged and the other undercharged.

This example of parallel plates, infinitely extended, is the ſimpleſt that can be ſuppoſed. But it cannot obtain under our obſervation; and in all caſes which we can obſerve, the fluid cannot be uniformly ſpread in any ſtratum, but muſt be denſer near the edges, or near the centre, as they are overcharged or undercharged.

98 Diſpoſition in a ſphere. Let ABD (fig. 19.) repreſent a ſphere of perfectly conducting matter, overcharged with electric fluid, which is perfectly moveable in its pores, but cannot eſcape from the ſphere. Let it be ſurrounded by con-

ducting matter ſaturated with moveable fluid. It is required to determine the diſpoſition of the fluid within and without this ſphere.

Sir Iſaac Newton has demonſtrated (*Princ.* I. 70.) that a particle p, placed anywhere within this ſphere, is not affected by any matter that is without the concentric ſpherical ſurface $p\ q\ r$ in which itſelf is ſituated, therefore not affected by what is between the ſurfaces ABD and $p\ q\ r$. He alſo demonſtrates, that the matter within the ſurface $p\ q\ r$ acts on the particle p in the ſame manner as if the whole of it were collected in the centre C.

Hence it follows, that the redundant fluid will be all conſtipated as cloſe as poſſible within the external ſurface of the ſphere, forming a ſhell of a certain minute thickneſs, between the ſpherical ſurfaces ABD and $a\ b\ d$; and all that is within this (that is, nearer the centre C) will be in its natural ſtate.

With reſpect to the diſtribution of the fluid in the ſurrounding matter, which we ſuppoſe to be infinitely extended, we muſt recollect that this ſhell of conſtipated redundant fluid repels any external particle of fluid in the ſame manner as if all were collected at C. Hence it is evident, that the fluid in the ſurrounding matter will be repelled, and, being moveable, it will recede from this centre; and there will be a ſpace all round the ſphere ABD which is undercharged, forming a ſhell between the concentric ſurfaces ABD and $\alpha\ \beta\ \delta$. This ſhell will contain ſuch a quantity of redundant matter, that its attraction for a particle of fluid is equal to the repulſion of the ſhell of fluid crowded internally on the ſurface ABD. All beyond this ſurface $\alpha\ \beta\ \delta$ will be in its natural ſtate; for this redundant matter acts on a particle of fluid, ſituated farther from the centre, in the ſame manner as if all this redundant matter were collected in the centre C. So does the redundant fluid in the conſtipated ſhell. Therefore their actions balance each other, and there is no force exerted on any particle of fluid beyond this deficient ſhell. This deficient ſhell will not affect the fluid in the ſphere $a\ b\ d$ by Newton's demonſtration. No other diſpoſition will be permanent. But farther: This undercharged ſhell muſt be completely exhauſted; for a particle of fluid placed between ABD and $\alpha\ \beta\ \delta$ will be more repelled by the fluid in the crowded ſhell within the ſurface ABD, than it is attracted by the redundant matter of its own ſhell that is leſs remote from the centre; and it is not affected by what is more remote from the centre. Therefore the fluid without the ſphere ABD cannot be in equilibrio, unleſs the ſhell between ABD and $\alpha\ \beta\ \delta$ be not only rarefied, but altogether exhauſted of fluid.

If the ſphere be undercharged, the ſpace between ABD and $a\ b\ d$ will be entirely exhauſted of fluid, and there will be a ſhell $\alpha\ \beta\ \delta$ of redundant matter ſurrounding the ſphere. All within $a\ b\ d$, and all without $\alpha\ \beta\ \delta$, will be in its natural ſtate. It is unneceſſary to repeat the ſteps of the ſame demonſtration.

This valuable propoſition is by the Hon. Mr Cavendiſh.

99 Conſequences of this diſpoſition.

This would be the diſpoſition in and about a glaſs globe filled and ſurrounded with an ocean of water, and having redundant fluid within it, on the ſuppoſition that glaſs is impervious to the electric fluid. But it would not affect an electrometer, even ſuppoſing that the movements of the electrometer could be affected under water. Suppoſe the globe of water to be ſurrounded with air, and that the fluid is diſpoſed in both in the manner here deſcribed; it will be perfectly neutral in its action on any electrometer ſituated in the air. But, by reaſon of the almoſt total immobility of the fluid in pure dry air, this ſtate cannot ſoon obtain; and, till it obtain, the conſtipated ſhell within the glaſs muſt repel the fluid in an electrometer more than the partially rarefied ſhell of air, which ſurrounds the glaſs, attracts it. By the gradual retiring of the fluid in the ſurrounding air from the globe, the attraction of the deſerted matter will come nearer to equality with the repulſion of the conſtipated ſhell within the glaſs, and the globe will appear to have loſt fluid. Yet it may retain all the redundant fluid which it had at the firſt. Therefore we are not to imagine that a body ſimilar to this globe has no redundant electric fluid, or only a ſmall quantity, becauſe we obſerve it inactive, or nearly ſo.

100 Vetrified by the phenomena.

Thus we ſee, as we proceed, that the Æpinian theory is adequate to the explanation of the phenomena. But we ſee it much more remarkably in a very familiar and amuſing experiment, uſually called the ELECTRIC WELL. See ELECTRICITY, *Encycl.* Sect. x. 4.

Electric Well explained.

To ſee it in perfection, make a glaſs veſſel of globular ſhape, with a narrow mouth, ſufficiently wide, however, to admit an electrometer ſuſpended to the end of a glaſs rod of a crooked form, ſo that the electrometer can be preſented to any part of the inſide. Smear the outſide of the globe with ſome tranſparent clammy fluid, ſuch as ſyrup. Set it on an inſulating ſtand (a wine glaſs), and electrify it poſitively. Hold the electrometer near it, anywhere without, and it will be ſtrongly affected. Its deviations from the perpendicular (if the ball of the electrometer has alſo been electrified) will indicate a force inverſely as the ſquare of the diſtance from the centre of the globe, pretty exactly, if the thread of the electrometer is of ſilk. Now let down the electrometer into the inſide of the globe. It will not be affected in any ſenſible degree, nor approach or avoid any body that is lying within the globe. The electrometer may be held in all parts of the globe, and when brought out again, is perfectly inactive and neutral. But if the balls of the electrometer be touched with a wire, while hanging free within the globe, they will, on withdrawing the wire, repel each other; and when taken out, they will be found negatively electrified. The experiment ſucceeds as well with a metal globe; nay, even although the mouth be pretty wide; in which caſe, there is not a perfect balance of action in every direction. The electrometer may be made to touch the bottom of the globe, or anywhere not too near the mouth, without acquiring any ſenſible electricity; but if we touch the outſide with the electrometer, it will inſtantly be electrified and ſtrongly repelled. Deep cylinders, and all round veſſels with narrow mouths, exhibit the ſame faintneſs of electricity within, except near the brims, although ſtrongly electric without; and even open metal cups have the interior electricity much diminiſhed.

101 Electric bodies are only ſuperficially ſo.

Reflecting on this valuable propoſition of Mr Cavendiſh, we ſee clearly why an overcharged electric is only ſuperficially ſo; and that this will be the caſe even although we attempt to accumulate a great quantity of electricity in it, by melting it in a thin glaſs globe, and

ways proportional to $c\,\delta$; and it might be expreſſed by $m \times c\,\delta$; m being a number expreſſing what part of $c\,\delta$ the ſum of $d\,\delta$ and $f\,\phi$ amounts to (perhaps $\frac{1}{10}$th, or $\frac{1}{20}$th, or $\frac{1}{30}$th, &c.). But in the caſe expreſſed in the figure, $d\,\delta$ does not increaſe ſo faſt as $c\,\delta$, and $f\,\phi$ increaſes faſter than $c\,\delta$. However, in the immediate neighbourhood of any point C, we may expreſs the accelerating force tending towards A by $\frac{m\,c\,\delta}{c\,\delta^2}\dot{x}$, without any ſenſible error; that is, by $m\frac{\dot{x}}{x}$; that is, by the fluxion of the area of a hyperbola HD′G, having CC′ and CK for its aſſymptotes; and the whole action of the fluid between F and D, on the particle C, will be expreſſed by the area C′CDD′H. Hence it follows, that the action of the ſmalleſt conceivable portion of the canal immediately adjoining to C on both ſides, or the difference of the actions of the two adjoining elements, is equal to the action of all beyond it. This ſhews, that the ſtate of compreſſion is hardly affected by any thing that is at a ſenſible diſtance from C; and that the denſity of the fluid, in an indefinitely ſlender canal, is, to all ſenſe, uniform. The geometer will alſo ſee, that the ſecond fluxion of D d is proportional to the force of the diſtant body. We learn, therefore, ſo much of the nature of the curve $b\,c\,e$.—(*Coulomb*).

We are now in a condition to examine the communication of electricity by means of conducting canals (which is one of the moſt important articles of the ſtudy), having found that the fluid, in a very ſlender canal, is very nearly of uniform denſity throughout.

106
Communication and transference by canals.

There can be no doubt but that, if a body B (fig. 22.) be overcharged or undercharged, any other body C, which communicates with it by a conducting canal, will alſo be overcharged or undercharged. It is as evident, that if a body, in any ſtate of electricity, be in the neighbourhood of an overcharged or undercharged body A, while it communicates with C by a canal leading from the ſide moſt remote from A, fluid will be driven from B into C, or abſtracted from C into B.

107
By crooked canals.

It is not, however, ſo clear, that when the canal leads from the ſide neareſt to A (as in fig. 23.), fluid will be driven from B into C. We conceive the fluid to be moveable in the body and in this canal, but not to eſcape from it. Its motion, therefore, in this caſe, ſhould, in the opinion of Mr Cavendiſh, reſemble the running of water in a ſyphon by the preſſure of the air. While the repulſion of the redundant fluid in A allows the bend of the ſyphon neareſt to A to retain fluid, a current ſhould take place from B along the ſhort leg, in conſequence of the ſuperior action on the fluid in the long leg. But if the repulſion of A can drive the fluid out of the bend between E and F, Mr Cavendiſh thinks, that it does not appear that fluid will come up from B in oppoſition to the repulſion of A, and then run along to D. But fluid does not move, in either of theſe caſes, on the principle of a ſyphon; becauſe there is nothing to hinder the fluid from expanding in the part EDF. And we are rather diſpoſed to think, that it will always move from B, over the bend, to C: For even if the fluid can be completely driven out of the bend EF, it muſt be done by degrees, and the fluid in the long leg will, from the very beginning of the action of A, be more moved from its place than that in the ſhort leg; and therefore will yield to the compreſſion, which acts tranſverſely, and, by thus yielding more toward F than toward E, the fluid will ruſh through the contracted part, and go into C. We do not ſay this with full confidence; but are thus particular, on account of an important uſe that may be made of the experiment. For if the body A be undercharged, fluid will certainly be attracted from C, and paſs over the bend into B, however great the action of A may be. Perhaps this may be ſo contrived, therefore, as to decide the long agitated queſtion, *Whether the electricity of excited glaſs be plus or minus?* If it be found that this apparatus, being preſented to the rubber of an electrical machine, diminiſhes the poſitive electricity of C, and increaſes that of B; but that, preſenting the ſame apparatus to the prime conductor, makes little change—we may conclude, that the electricity of the prime conductor is poſitive. We have tried the experiment, paying attention to every circumſtance that ſeemed likely to inſure ſucceſs; but we have always found hitherto, that the apparatus was equally affected by both electricities.

Propoſal for diſcovering redundancy of fluid.

We muſt now conſider the action of electrified bodies on the canals of communication; becauſe this will give us the eaſieſt method of aſcertaining the proportion in which the expelling fluid is diſtributed between them. For when two bodies communicate by a canal, and have attained a permanent ſtate, we muſt conceive that their oppoſite actions on the fluid moveable along this canal are in equilibrio, or are equal. This will generally be a much eaſier problem than their action on each other, ſince we have ſeen a little a ago, that the fluid in a ſlender canal is of uniform denſity very nearly. A very few examples of the moſt important of the ſimple caſes muſt ſuffice.

108
Action of a plate on a rectilineal canal.

Therefore let AC a (fig. 24.) repreſent the edge of a thin conducting circular plate, to which the ſlender canal CP is perpendicular in the centre. It is required to determine the action of the matter or fluid, uniformly ſpread over this plate, on the fluid moveable in the canal PC?

109 1. Required the action of a particle in A on the fluid in the whole canal? Join AP; and call CP x, AP y, and AC r; and let f expreſs the intenſity of action at the diſtance 1, or the unit of the ſcale on which the lines are meaſured.

The action of A on P, in the direction AP, is $\frac{f}{y^2}$. This, when eſtimated in the direction CD, is reduced to $\frac{f}{y^2} \times \frac{x}{y}$; and is therefore $= f\frac{x}{y^3}$. Therefore the fluxion of the action, in the direction CP, on the whole canal, is $f\frac{x}{y^3}\dot{x} = f\frac{y\dot{y}}{y^3}$ (becauſe $x : y = \dot{y} : \dot{x}$) $= f \times \frac{\dot{y}}{y^2}$. The variable part of the fluent is $= f\frac{-1}{y}$, and the complete fluent is $= f\left(C - \frac{1}{y}\right)$, where C is a conſtant quantity, accommodated to the nature of the caſe. Now, the action muſt vaniſh when the canal vaniſhes, or when $x = 0$, and $y = r$. Therefore $C - \frac{1}{r} = 0$, and $C = \frac{1}{r}$; and the general expreſſion

preſſion of the action is $f\left(\frac{1}{r}-\frac{1}{y}\right), =f\frac{y-r}{ry}$, expreſſing the action of a particle in the circumference of the plate on the fluid in the whole canal CP.

2. Required the action of the plate, whoſe diameter is A a, on the particle P?

110 1. On a ſingle particle in the canal

Let a repreſent the area of a circle, whoſe diameter is $=1$. Then ar^2 is the area of the plate, and $2ar\dot{r}$ is the fluxion of this area; becauſe $r:y=\dot{y}:\dot{r}$, $2ar\dot{r}$ is $=2ay\dot{y}$. Therefore the fluxion of the action of the plate on the particle P is $f\times 2ay\dot{y}\times\frac{x}{y^3}, =2fa$ $x\times\frac{\dot{y}}{y^2}$. The fluent of this has for its variable part $2fax\times\frac{-1}{y}$ (for when the particle P is given, x does not vary). This is $=2fa\times\frac{-x}{y}$. To complete this fluent, we muſt add a conſtant quantity, which ſhall make the fluent $=0$ when the particle P is at an infinite diſtance; and therefore when $x=y$. Therefore $\frac{y}{y}-\frac{x}{y}=0$, or $1-\frac{x}{y}=0$, or $C=1$; and the complete fluent for the whole plate is $2fa\left(1-\frac{x}{y}\right)$.

111 The meaning of this expreſſion may not occur to the reader: For $1-\frac{x}{y}$ is evidently an abſtract number; ſo is a. Therefore the expreſſion appears to have no reference to the ſize of the plate. But this agrees with the obſervation in n° 91. where it was ſhewn, that provided the angle of the cone or pyramid remained the ſame, the magnitude of the baſe made no change in its attraction or repulſion for a particle in the vertex.

It will appear by and bye, that $1-\frac{x}{y}$ is a meaſure or function of a certain angle of a cone.

Cor. If PC be very ſmall in proportion to AC, the action is nearly the ſame as if the plate were infinite: For when the plate is infinite, $\frac{x}{y}$ is $=0$, and the action is $=1$, whatever is the diſtance (ſee n° 91—93). Therefore, when x is very ſmall in compariſon of r, and conſequently of y, $1-\frac{x}{y}$ is very nearly $=1$.

112 2. On the whole canal.

3. To find the action of the plate on the whole column?

The fluxion of this muſt be $=2fa\times\left(1-\frac{x}{y}\right)\dot{x}$, or $2fa\left(\dot{x}-\frac{x\dot{x}}{y}\right)$, or $2fa\times(\dot{x}-\dot{y})$; becauſe $\dot{y}=\frac{x\dot{x}}{y}$. The fluent of this has for its variable part $2fa\times(x-y)$. A conſtant quantity muſt be added, which ſhall make it $=0$ when the column $=0$; that is, when $y=r$, and $x=0$; that is, $C-r=0$, and $C=r$. Therefore the complete fluent is $=2fa(x+r-y)$.

113 Geometrical expreſſion of theſe actions.

Thus have we arrived at a moſt ſimple expreſſion of the attraction or repulſion of a plate for ſuch a column, or for portions of ſuch a column. And it is moſt eaſily conſtructed geometrically, ſo as to give us a ſenſible image of this action of eaſy conception and remembrance. It is as follows: Produce PC till CK = CA, and about the centre P deſcribe the arch AI, cutting CK in I. Then $2fa\times$ IK is evidently the geometrical expreſſion of the attraction or repulſion. This is plainly a cylinder, whoſe radius is a unit of the ſcale, and whoſe height is twice IK.

In like manner, by deſcribing the arch A i round the centre p, we have $2fa\times i$K for the action of the plate on the ſmall column Cp; and $2fa\times$ I i is the action of the plate on the portion P p.

The general meaning of the expreſſion $2fa\times$ IK is, that the action of the whole plate on the column PC is the ſame as if all the fluid in the cylinder $a\times 2$ IK, were placed at the diſtance 1 from the acting particle.

From this propoſition may be eaſily deduced ſome very uſeful corollaries by the help of the geometrical conſtruction.

114 1. If PC be very great in compariſon with AC, the action is nearly the ſame as if the column were infinitely extended; for in this caſe IK is very nearly = CK, the difference being to the whole nearly as AC to twice AP.

115 Important corollary.

2. If, in addition to this laſt condition, another column p C be very ſmall in compariſon of AC, then the action on PC is to that on p C very nearly as p C to AC. For it will appear that i K : IK = p C : AC very nearly. It is exactly ſo when CP : CA = CA : C p; and it will always be in a greater proportion than that of p C to IK.

This will be found to be a very important obſervation.

The redundant fluid has hitherto been ſuppoſed to be uniformly ſpread over the plate: but this cannot be; becauſe its mutual repulſion will cauſe it to be denſer near the circumference. We have not determined, by a formula of eaſy application, what will be the variation of denſity. Therefore let us conſider the reſult of the extreme caſe, and ſuppoſe the whole redundant fluid to be crowded into the circumference of the plate, as we ſaw that it muſt be on the ſurface of a globe.

116 Action of a circumference on a canal.

In this caſe the action on the fluid in the canal will be $fa\left(r-\frac{r^2}{y}\right)$. For the area of the plate is ar^2, and the action of a particle in the circumference on the whole canal was ſhewn (n° 109) to be $f\left(\frac{y-r}{ry}\right)$. Therefore the action of the whole fluid crowded into the circumference is $far^2\times\frac{y-r}{ry}, =far\frac{y-r}{y}$. It may be repreſented as follows: Deſcribe the quadrant C b BE, cutting AP and A p in B and b. Draw BD and b d parallel to PC. Then PB $=y-r$, and DC $=r\frac{y-r}{y}$. Therefore the action is repreſented by f multiplying a cylinder, whoſe radius is 1 and height is DC. In like manner, d C is the height of the cylinder correſponding to the column p C, and D d the height correſponding to P p.

117 *Cor.* 1 When CP is very great in compariſon with CA, the point D is very near to A, and I is very near to C, and CD is to IK nearly in the ratio of equality.

In this caſe the action of the fluid, uniformly ſpread over the plate, is nearly double of the action of the ſame fluid crowded round the circumference; for they are as cylinders, having the ſame baſes and heights in the ratio of 2 IK to DC, which is nearly the ratio of 2 to 1.

118 2. On the other hand, when the column p C is very ſhort, the action of the fluid ſpread uniformly over the plate is to its action, when crowded round the circumference, nearly in the ratio of 4 AC to p C. For theſe actions are in the ratio of $2\ fa \times i$ K to $1\ fa \times d$ C, or as $2\ i$ K to d C, or nearly as $2\ p$ C to d C, or more nearly as $2\ bd$ to d C. But C $d : bd = bd : b$ A $+$ A d, or nearly $= bd : 2$ CA. Therefore C $d : 2\ bd = p$ C : 4 CA nearly.

119 Hence we ſee that the action on ſhort columns is much more diminiſhed by the receſs of the redundant fluid toward the circumference than that on long columns. Therefore, any external electric force which tends to ſend fluid along this canal, and from thence to ſpread it over the plate, will ſend into the place a greater quantity of fluid than if the fluid remained ultimately in a ſtate of uniform diſtribution over its ſurface; and that the odds will be greater when the canal is ſhort.

120 Equivalent centre of action.

Laſtly, on this ſubject, If KL be taken equal to AP, or PL be equal to KI, the repulſion which all the fluid in the plate, collected in K, would exert on the fluid in the canal CL, is equal to the repulſion which the ſame fluid, conſtipated in the circumference, would exert on the column CP. For we have ſeen that the action of a particle in A on the whole column PC, when eſtimated in the direction PC, is $\frac{y-r}{yr}$; and it is well known that the the action of a particle in K for the column CL is $\frac{1}{\text{KC}} - \frac{1}{\text{KL}}$, or $\frac{1}{r} - \frac{1}{y}, = \frac{y-r}{yr}$. Therefore the action of the whole fluid, collected in the circumference, on the column CP is equal to that of the ſame fluid, collected in K, on the columns CL.

121 *Cor.* 1. If the column CP is very long in proportion to AC or KC, the actions of the fluids in theſe two different ſituations are very nearly the ſame. The action of the fluid collected in K exceeds its action when collected in A only by its action on the ſmall and remote column LP. The action of all the fluid collected at K on the column CP, is eaſily had by taking C l = KP. It is equal to the action of the ſame fluid placed in A on the column C l.

122 *Cor.* 2. The action of all the fluid uniformly ſpread, exerted on the column CP, is to the action of the ſame fluid collected in K, exerted on the column CL, as 2 IK to CD.

123 If the column CP is very great in proportion to AC, the half breadth of the plate, the action in the firſt caſe is very nearly double of the action in the other caſe, and is exactly in this proportion if CP is of infinite extent.

124 Action of a ſpherical ſurface, or ſhell, or ſolid, on the ſame canal.

Cor. 3. If CNO be a ſpherical ſurface or ſhell of the ſame thickneſs and diameter as the plate A a, and containing redundant fluid of the ſame uniform denſity, the action of this fluid on the column CL is double of the action of the fluid uniformly ſpread over the plate on the column CP, and quadruple of the action of the fluid collected in the circumference: for the action is the ſame as if all were collected in the centre K, and the ſurface of the ſphere is four times that of the plate, and therefore they are as IK to 2 CD.

Let us now conſider the comparative actions of different plates or ſpheres on the canals.

125 Actions of two plates, or two ſpheres, are as their diameters, when the canals are infinitely long.

If two circular plates, DE, de (fig. 25.), or two ſpherical ſhells, ABO, abo, of equal diameters and thickneſs with the plates, and containing redundant fluid of equal denſity, communicate with infinitely extended ſtraight canals OP, op, paſſing through their centres perpendicular to their ſurfaces, alſo containing fluid uniformly diſtributed and of equal denſity—the repulſions will be as the diameters. For the repulſion of the ſpherical ſurfaces is the ſame as if all the fluid were collected at their centres; and the repulſion of the fluid uniformly ſpread over the ſurfaces of the plates is double of its repulſion if collected at the centres of theſe ſpheres; it follows, that the repulſions of the plates are proportional to thoſe of the ſphere. But becauſe the repulſion of a plate whoſe radius is r was ſhewn to be $= 2\,a \times \overline{r+x-y}$, and when the column is infinitely extended, x is equal to y, and $\overline{r+x-y} = r$, it follows, that the repulſions of the plates are as $2\,a \times$ R and $2\,a \times r$, or proportional to their diameters. Therefore the repulſions of the ſpheres are in the ſame proportion.

126 *Cor.* 1. If the canals are very long in proportion to the diameters of the plates or ſpheres, the repulſions are nearly in the ſame proportion.

127 The proportion of the greateſt action is diminiſhed if the canals are ſhort.

Cor. 2. But as the lengths of the canals diminiſh, the repulſions approach to equality; for it was ſhewn, that when the canal was very ſmall, the repulſion was to that for an infinite column as the length of the canal to the radius of the plate. Therefore if the radius of the greater plate be (for example) double of that of the ſmaller, and the little columns be $\frac{1}{20}$th of the radius, it will be $\frac{1}{10}$th of the radius of the ſmaller plate. Now $\frac{1}{10}$th of half the repulſion is equal to $\frac{1}{20}$th of the double repulſion. Alſo, in the caſe of the ſpheres, the repulſion of a particle at the ſurface is as the quantity of fluid directly, and as the ſquare of the radius inverſely; but when the denſity is the ſame in both ſhells, the quantity is as the ſurface, or as the ſquare of the radius. Therefore the repulſions are equal.

128 Actions of two ſpheres are equal if the denſity be inverſely as the diameters;

Cor. 3. If the denſity of the fluid in two ſpherical ſhells be inverſely as the diameters, the repulſions for an infinitely extended column of fluid are equal; for each repels as if all the fluid was collected in the centre. Therefore, if the denſity, and conſequently the quantity, be varied in any proportion, the repulſion will vary in the ſame proportion. The repulſions will now be as CO $\times \frac{1}{\text{CO}}$ to $co \times \frac{1}{co}$, or in the ratio of equality.

129 Or if the quantity of redundant fluid be as the diameters.

Cor. 4. When the quantities of redundant fluid in two ſpheres are proportional to their diameters, their repulſions for an infinitely extended canal are equal: for if this redundant fluid is conſtipated in the ſurfaces of the ſpheres, as it always will be when they conſiſt of conducting matter, the denſities are as the diameters inverſely, becauſe the ſurfaces are as the ſquares of the diameters. Therefore, by the laſt corollary, their actions on an infinitely extended canal are equal. But in ſpheres of non-conducting matter it may be differently, diſpoſed, in concentric ſhells of uniform denſity.

This makes no change in the action on the fluid that is without the ſphere, becauſe each ſhell acts on it as if it were all collected in the centre. Therefore the repulſions are ſtill equal.

130
Two ſpheres overcharged in this proportion are in equilibrio if communicating by a very long canal.

Cor. 5. Two overcharged ſpheres, or ſpherical ſhells, OAB, *o a b* (fig. 26.), communicating by an infinitely extended canal of conducting matter, contain quantities of redundant fluid proportional to their diameters; for their actions on the fluid in the interjacent canal muſt be in equilibrio, and therefore equal. This will be the caſe only when the quantities of fluid are in the proportion of their diameters.

When the canals are very long in proportion to the diameters of the ſpheres, the proportion of the quantities of redundant fluid will not greatly differ from that of the diameters.

131 *Cor.* 6. When the ſpheres of conducting matter are thus in equilibrio, the preſſures of the fluid on their ſurfaces are inverſely as their diameters; for the repulſion of a particle at the ſurface is the ſame with the tendency of that particle from the centre of the ſphere, the actions being mutual. Now this is proportional to the quantity of redundant fluid directly, and to the ſquare of the diſtance from the centre inverſely, that is, to the diameter directly, and to the ſquare of the diameter inverſely, that is, to the diameter inverſely.

Tendency of the fluid to eſcape is inverſely as the diameter.

Hence it follows, that the tendency to eſcape from the ſpheres is inverſely as the diameter, all other circumſtances being the ſame: for in as far the eſcape proceeds from mere electric repulſion, it muſt follow this proportion. But there are evident proofs of the co-operation of other phyſical cauſes. We obſerve chemical compoſitions and decompoſitions accompanying the eſcape of electric fluid, and its influx into bodies: we are ignorant how far, and in what manner, theſe operations are affected by diſtance. Boſcovich ſhews moſt convincingly, that the action of a particle (of whatever order of compoſition), on external atoms and particles, is ſurpriſingly changed by a change in the diſtance and arrangement of its component atoms. A conſtipation, therefore, to a certain determined degree and lineal magnitude, may be neceſſary for giving occaſion to ſome of thoſe chemical operations that accompany, and perhaps occaſion, the eſcape of the electric fluid. If this be the caſe (and it is *demonſtrable* to be poſſible, if the operations of Nature be owing to attractions and repulſions), the eſcape *muſt* be deſultory. It is actually ſo; and this confirms the opinion.

The public is indebted to Mr Cavendiſh for the preceding theorems on the action of ſpheres and circular plates. He has given them in a more abſtract and general form, applicable to any law of electric action which experience may warrant. We have accommodated them to the inverſe duplicate ratio of the diſtances, as a point ſufficiently eſtabliſhed; and we hope that we have rendered them more ſimple and perſpicuous. We have availed ourſelves of Mr Coulomb's demonſtration of the uniform denſity in the canal, without which the theorems could not have been demonſtrated. The minute quantity of the fluid in the canal can have no ſenſible effect on the diſpoſition or proportion of the fluid in the plates or ſpheres.

This propoſition agrees with hydroſtatical laws.

It may be thought that the laſt corollary, reſpecting the equilibrium of two ſpheres, is not agreeable to hydroſtatical principles, which require the equality of the two forces which balance each other at the orifices of the ſlender cylindric canal; whereas, in that corollary the forces at the extremities of the canal are inverſely as the diameters of the ſpheres or plates. This would be a valid objection, if the compreſſing forces acted only on the extremities of the canals; but they act on every particle through their whole length. It is not, therefore, the preſſure at one end of the canal that is in equilibrio with the preſſure at the other end, by the interpoſition of the fluid. It is the preſſure at one end, together with the ſum of all the intermediate preſſures in that direction, that is in equilibrio with all the preſſure in the oppoſite direction. The preſſures at the ends are only parts of the whole oppoſite preſſures; they are the firſt in each account. In this manner a ſlender pipe, having a ball at each end, may be kept filled with mercury, while lying horizontal, if the air in each ball is of equal denſity. But if it be raiſed perpendicular to the horizon, it cannot remain filled from end to end, unleſs the air of the ball below be made ſo elaſtic by condenſation, that its preſſure on the lower orifice of the pipe exceed the preſſure of the air in the upper ball on the other orifice by a force equal to the weight of the mercury, that is, to the aggregate of the action of gravity on each particle of mercury in the pipe. Therefore the repulſions of the ſpheres that we are ſpeaking of are in equilibrio by the intervention of the fluid in the canal, in perfect conſiſtency with the laws of hydroſtatical preſſure.

Mr Cavendiſh has purſued this ſubject much farther, and has conſidered the mutual action of more than two bodies, communicating with each other by canals of moveable fluid uniformly denſe. But as we have not room for the whole of his valuable propoſitions, we ſelected thoſe which were elementary and leading theorems, or ſuch as will enable us to explain the moſt important phenomena. They are alſo ſuch, as that the attentive reader will find no difficulty in the inveſtigation of thoſe which we have omitted.

132
General propoſition with reſpect to the ſtate of communicating bodies.

Mr Cavendiſh's moſt general propoſition is as follows:

When an overcharged body communicates, by a canal of *very great* length, ſtraight or crooked, with two or more ſimilar bodies, alſo at a very great diſtance from each other, and all are in electric equilibrium, and conſequently each body overcharged in a certain determined proportion, depending on its magnitude, if any two of theſe bodies are made to communicate in the ſame manner, their degrees of electricity are ſuch, that no fluid will paſs from one to the other, their mutual actions on the fluid in this canal being alſo in equilibrio. He brings out this by induction and combination of the ſingle caſes, each of which he demonſtrates by means of the following theorem:

133
It is indifferent whether the canal be ſtraight or crooked.

The action of an overcharged ſphere ACB (fig. 25.) on the fluid in the whole of a canal *d f* P that is oblique tending to impel the fluids in the direction of that canal, is equal to its action on the fluid in the whole of the rectilineal canal CP. Let *h i* be a minute portion of the ſtraight canal, and *f d* the portion of the crooked canal which is equidiſtant from the centre C of the ſphere; draw the radii C *f* C *d*, and the concentric arches *h f*, *i d*, cutting *f* C in *g*; and draw *g e* perpendicular to *f d*; the force acting on *i h*, impelling it toward P, may be repreſented by *h i*. The ſame force acting on df, in the direction cf, muſt therefore be expreſſed by gf. This, when eſtimated in the direction of the canal df, is reduced to ef; but it is exerted on each particle of df. Now $df : gf = gf : ef$, and $df \times ef = gf^2, = gf \times hi$; therefore the whole force on df, in the direction df, is equal to the force on ih, in the direction ih. Hence the truth of the propoſition is manifeſt.

We beg the curious reader to apply this to the caſe in hand, and he will find, that the moſt complicated caſes may all be reduced to the ſimple ones which we have demonſtrated to be ſtrictly true when the bodies are ſpheres or plates, and the canals infinitely long and which are very nearly true when the canals are *very long*, and the bodies ſimilar: And we now proceed to one compound caſe more, which includes all the moſt remarkable phenomena of electricity.

134 Curious and very important caſe of four plates.

Let HK, AB, DF, and LM (fig. 27.) be four parallel and equal circular plates, two of which, HK and AB communicate by a canal GC of indefinite extent, joining their centres, and perpendicular to their planes; let DF and LM be connected in the ſame manner, and let the two canals be in one ſtraight line: let the plate HK be overcharged, and the plate LM juſt ſaturated. It is required to determine the diſpoſition and proportion of the electric fluid in the plates which will make this condition of HK and LM poſſible and permanent, every thing being in equilibrio?

The plate HK being overcharged, and communicating with AB, AB, muſt be overcharged in the ſame manner, and being alſo equal to HK, it muſt be overcharged in the ſame degree containing an equal quantity of redundant fluid diſpoſed in the ſame manner. To ſimplify the inveſtigation, we ſhall firſt ſuppoſe that the redundant fluid is uniformly ſpread over the ſurfaces of both.

When the plates HK and AB are in this ſtate, let the plates DF and LM be brought near them, as is repreſented in the figure, CE being the diſtance of the centres of AB and DF. It is evident, that the redundant fluid in AB will act on the natural moveable fluid in DF, and drive ſome of it along the canal EN, and render LM overcharged. Take off this redundant fluid in LM. This will diminiſh or annihilate the repulſion which it was beginning to exert on the canal EN; therefore more fluid will come out of DF, and again render LM overcharged. The redundant fluid in LM may again be taken off, in leſs quantity than before, as is plain. Do this repeatedly till no more can be taken off. But this will undoubtedly render DF undercharged, and it will now contain redundant matter. This will act on the fluid in the canal GC, and abſtract it from G; therefore fluid will come out of HK into AB. HK will be leſs overcharged than before, and AB will be more overcharged. But the now increaſed quantity of redundant fluid in AB will act more ſtrongly on the moveable fluid in DF, and drive more out of it. This will leave more redundant matter in it than before, and this will act as before on the fluid in the canal GC. This will go on, by repeatedly touching LM, till at laſt all is in equilibrio. Or this ultimate ſtate may be produced at once by allowing LM to communicate with the ground. And now, in this permanent ſtate of things, HK contains a certain quantity of redundant fluid; AB contains a greater quantity; DF contains redundant matter; and LM contains its natural quantity. The demand of the problem therefore is to determine the proportion of the redundant fluid in HK to that in AB, and the proportion of the redundant fluid in AB to the deficiency of fluid in DF. The dynamical conſiderations which determine theſe proportions are, 1*ſt*, The repulſion of the redundant fluid in AB, for the fluid in the canal EN, muſt be preciſely equal to the attraction of the redundant matter in DF for the ſame fluid in the canal; for LM being ſaturated, is neutral. 2*d*, The repulſion of the redundant fluid in HK, for the whole fluid in the canal GC, muſt balance the exceſs of the repulſion of the redundant fluid in AB above the attraction of the redundant matter in DF for the ſame.

Let the redundant fluid in AB be $= f$.
the redundant matter in DF $= m$.
the redundant fluid in HK $=$ F.

Becauſe HK and AB are equal, there can be no doubt but that the fluid in thoſe plates would be ſimilarly diſpoſed; and it is highly probable, that if AB be very near DF, the redundant fluid in AB, and the redundant matter in DF will alſo be diſpoſed nearly in the ſame manner. This will appear plainly when we conſider with attention the forces acting between a very ſmall portion of AB and the correſponding portion of DF. The probability that this is the caſe is ſo evident, that we apprehend it unneceſſary to detail the proofs. We ſhall afterwards conſider ſome circumſtances which ſhew that the diſpoſition in the three plates will (though nearly ſimilar) be nearer to a ſtate of uniform diſtribution than if only AB and HK had been in action. Aſſuming therefore this ſimilarity of diſtribution, it follows, that their actions on the fluid in the canals will be ſimilar, and nearly proportional to their quantities.

Therefore let 1 be to n as the repulſion of the fluid in AB, for the fluid that would occupy CE, is to its repulſion for the fluid in EN or CG.

Then the action of AB on EN is $f \times \overline{n - 1}$, and the action of DF on EN is $m\,n$; therefore, becauſe the plate LM is inactive, the actions of AB and DF on EN muſt balance each other, and $f \times \overline{n - 1} = m\,n$, and $m = f \times \frac{n - 1}{n}$.

The repulſion of f for the fluid in CG is $f\,n$. The attraction of m for it is $m \times \overline{n - 1}$; and becauſe $m = f \times \frac{n - 1}{n}$, the attraction of m for the fluid in CG is $f \times \frac{\overline{n - 1}}{n} \times \overline{n - 1}$. Therefore the repulſion of f is to the attraction of m as $f\,n$ to $f \times \frac{\overline{n - 1}^2}{n}$, or as $f\,n^2$ to $f \times \overline{n - 1}^2$, or as n^2 to $\overline{n - 1}^2$. Call the repulſion of f r, and the attraction of m a.

We have $r : a = n^2 : \overline{n - 1}^2$
and $r : r - a = n^2 : n^2 - (n - 1)^2 = n^2 : 2\,n - 1$.

Therefore, becauſe the repulſion of F is equal to this exceſs of r above a, we have $n^2 : 2\,n - 1 = f :$ F, and F $= f\frac{2\,n - 1}{n^2}$, or $f =$ F$\frac{n^2}{2\,n - 1}$. Therefore, if n^2 is much greater than $2\,n - 1$, the quantity of redundant fluid in AB will be much greater than the quantity in HK.

135 Prodigious accumulation of redundant fluid;

Now, when the electric action is inverſely as the ſquare of the diſtance, and EC is very ſmall in compariſon with AC, we have ſeen (n° 115.) that 1 : n nearly = CE : CA, or that n is nearly $\frac{AC}{EC}$. When this is the caſe, and conſequently n is a conſiderable number, we may take the number $\frac{n^2}{2n}$ for $\frac{n^2}{2n-1}$ without any great error. In this caſe f is equal to $F\times\frac{n}{2}$ very nearly. Suppoſe CA to be ſix inches, and CE to be $\frac{1}{20}$th of an inch; this will give $n = 120$, and $f = 60$ F; or, more exactly, $F = \frac{n^2}{2n-1} = \frac{14{,}400}{239}$; $= 60\frac{1}{4}$. If, inſtead of the plate HK, we employ a globe of the ſame diameter, f will be but half of this quantity, or $f = F\times\frac{n}{4}$ (n° 123 124.).

136 And evacuation:

It alſo appears, that when the plates AB and DF are very near to each other, and conſequently n a large number, the deficiency in DF is very nearly equal to the redundancy in AB. In the example now given, m is $\frac{59}{60}$ of f, being $= f\times\overline{n-1}$.

137 Yet no very ſenſible appearance.

Yet this great deficiency in DF does not make it electrical on the ſide toward LM. It is juſt ſo much evacuated, that a particle of fluid at its ſurface has no tendency to enter or to quit it.

Laſtly, this great quantity of fluid collected in AB does not render it more electrical than HK.

In general, things are in the condition treated of in n° 22, 23, &c.

The attentive reader will readily ſee, that this account of the apparatus of four plates is only an approximation to the condition that really obtains under our obſervation. Our canals are not of indefinite length, nor occupied by fluid that is diſtributed with perfect uniformity; nor is the fluid uniformly ſpread over the ſurface of the plates. He will alſo ſee, that the real ſtate of things, as they occur in our experiments, tends to diminiſh the great diſproportion which this imaginary ſtatement determines. But when the canals are very long, in compariſon with the diameters of the plates, and AB is very near to DF, the difference from this determination is inconſiderable. We ſhall note theſe differences when we conſider the remarkable phenomena that are explained by them.

In the mean time, we ſhall juſt mention ſome ſimple conſequences of the preſent combination of plates.

138 Method of deſtroying this great accumulation: 1. By degrees;

Suppoſe AB touched by a body. Electric fluid will be communicated. But by no means all the redundant fluid contained in AB: only as much will quit it as will reduce it to a neutral ſtate, if the body which touches it communicates with the ground; that is, till the attraction of the redundant matter in DF attracts fluid on the remote ſide of AB as much as the redundant fluid left in AB repels it. When this has been done DF is no longer neutral; for the repulſion of AB for the fluid in EN is now diminiſhed, and therefore the attraction of DF will prevail. If we now touch DF, it may again become neutral with reſpect to EN; but AB will now repel again the fluid in CG, and again be electric on that ſide by redundancy. Touching AB a ſecond time takes more fluid from it, and DF again becomes electric by deficiency, and attracts fluid on that ſide.—And thus, by repeatedly touching AB and DF alternately, the great accumulation of fluid in AB may be exhauſted, and the nearly equal deficiency in DF may be made up.

139 2. All at once.

But this may be done in a much more expeditious way. Suppoſe a ſlender conducting canal *a b d* brought very near to the outſides of the plates, the end *a* being near to A, and the end *d* to D. The vicinity of *a* to A cauſes the fluid in *a b* to recede a little from *a* by the repulſion of the redundant fluid in AB. This will leave redundant matter in *a*, which will ſtrongly attract the redundant fluid from A, and *a* may receive a ſpark. But the conſequence, even of a nearer approach of the fluid to the outward ſurface of A, will render the correſponding part of DF more attractive, and the retiring of fluid from *a* along *a b* will puſh ſome of its natural fluid toward *d*; and thus A becomes more diſpoſed to give out, and *a* to take it in, while *d* is diſpoſed to emit, and D to attract. Thus, every circumſtance favours the paſſage of the whole, or almoſt the whole, redundant fluid to quit AB at A, to go along *a b d*, and to enter into DF at D.

140 The plates ſtrongly attract each other.

It is plain, that there muſt be a ſtrong tendency in the fluid in AB to go into DF, and that the plates muſt ſtrongly attract each other. A particle of fluid ſituated between them tends toward DF with a force, which is to the ſole repulſion of AB nearly as twice the redundant fluid in it to what it would contain if electrified to the ſame degree while ſtanding alone.

With this particular and remarkable caſe of induced electricity, we ſhall conclude our explanation of Mr Æpinus's Theory of Electric Attraction and Repulſion. The reader will recollect, that we began the conſideration of the diſpoſition of the electric fluid in bodies, in order to deduce ſuch legitimate conſequences of the hypothetical law of action as we could compare with the phenomena.

141 Method of examining the validity of this theory.

Theſe compariſons are abundantly ſupplied by the preceding paragraphs, particularly by n° 74, 75, 76; by n° 130, and by n° 134.

Let a ſmooth metal ſphere be electrified poſitively in any manner whatever, and then touch it with a ſmall one in its natural ſtate. The redundant fluid is divided between them in a proportion which the theory determines with accuracy. By the theory alſo the redundant fluid in both acts as if collected in the centre. Therefore the proportion of the repulſions is determined. Theſe can be examined by our electrometer. But, as this menſuration may be ſaid to depend on the truth of the theory, we may examine this independent of it. Let the balls be equal. Then the redundant fluid is divided equally between the bodies, whatever be the law of action. Therefore obſerve the electrometer, as it is affected by the electrified body, both before and after the communication. This will give the poſitions of the electrometer which correſpond to the quantities 2 and 1.

142 Graduation of electrometer.

Take off the electricity of one of the balls by touching it, and then touch the other ball with it. This

will

it with ſingular ſucceſs in the explanation of the phenomena of attraction and repulſion, as we have already ſeen. In no part of the ſtudy has his ſucceſs been ſo conſpicuous as in the explanation of the curious and important phenomena of the Leyden phial. It only remained for him to account for the accumulation of ſuch a prodigious quantity of this agent as was competent to the production of effects which ſeemed to exceed the ſimilar effects in other caſes, out of all proportion. Indeed, the diſproportion is ſo great, as to make them appear to be of a different and incomparable nature. Dr Wilſon's experiments in the pantheon are therefore precious, by ſhewing that nothing was wanted for the production of all the effects of the Leyden phial but a ſurface ſufficiently extenſive for containing a vaſt quantity of fluid, and ſo perfectly conducting as to admit of its ſimultaneous and rapid transference. Therefore we aſſert, that one of the chief merits of Mr Æpinus's theory is the ſatisfactory explanation of the accumulation of this vaſt quantity of fluid in a ſmall ſpace. We truſt, therefore, that our readers will peruſe it with pleaſure. But we muſt here obſerve, that Mr Æpinus has not expreſsly done this in the work which we have already made ſo much uſe of, nor in any other that we know of. He has gone no farther than to point out to the mathematicians, that his hypotheſis is adequate to the accounting for any degree of accumulation whatever. This he does in that part of his work which contains the formulæ of n° 38, 39, 40, 41, &c. And he afterwards ſhews, that all the phenomena of attraction and repulſion which are obſerved in the charged jar are preciſely ſuch as are neceſſary conſequences of his theory.

148
Theory of charged glaſs completed by Mr Cavendiſh.

It is to the Hon. Mr Cavendiſh that we are indebted for the ſatisfactory, the complete (and we may call it *the proper*), explanation of all the phenomena. Forming to himſelf the ſame notion of the mechanical properties of the electric fluid with Mr Æpinus, he examined, with the patience, and much of the addreſs, of a Newton, the action of ſuch a fluid on the fluid around it, and the ſenſible effects on the bodies in which it reſided; the diſpoſition of it in a conſiderable variety of caſes; and particularly its action on the fluid contained in ſlender canals and in parallel plates;—till he arrived at a ſituation of things ſimilar to the Leyden phial. And he then pointed out the preciſe degree of accumulation that was attainable, on different ſuppoſitions concerning the law of electric action in general. We have given an abſtract of this inveſtigation accommodated to the inverſe duplicate ratio of the diſtances.

149

From this it appears (n° 135), that whatever quantity of electric fluid we can put into a circular plate 12 inches in diameter, by ſimple communication with the prime conductor of an electrical machine, we can accumulate 60 times as much in it by bringing the plate within $\frac{1}{20}$th of an inch of another equal plate which communicates with the ground; and it appears in n° 139, that all this accumulated fluid may be transferred in an inſtant to the other plate (which is ſhewn to be almoſt equally deprived of fluid), by connecting the two plates by a ſmall wire.

But as it was alſo ſhewn in that paragraph, that the force with which the accumulated fluid was attracted by the redundant matter in the other plate was exceedingly great, and conſequently its tendency to eſcape was proportionably increaſed; this accumulation cannot be obtained unleſs we can prevent this ſpontaneous transference.

150
Inexplicable by material atmoſpheres.

Here the non-conducting power of idio-electrics, without any diminution, the action of the electric fluid on fluid or matter on the other ſide of them, comes to our aid, and we at once think of interpoſing a plate of glaſs, or wax, or roſin, or any other electric, between our conducting plates. Such is the immediate ſuggeſtion of a perſon's mind who entertains the Æpinian notion of the electric fluid; and ſuch, we are convinced, is the thought of all who imagine that they underſtand the phenomena of the Leyden phial. But thoſe who attempt to explain electric action by means of what they call electric atmoſpheres of variable denſity or intenſity, are not intitled to make any ſuch inference, nor to expect any ſuch phenomena as the Leyden phial exhibits. Electricity, they ſay, acts by the intervention of atmoſpheres: Therefore, whatever allows the propagation of this action (conceive it in any manner whatever), allows the propagation of theſe agents; and whatever does not conduct electric action, does not conduct the agents. Interpoſed glaſs ſhould therefore prevent all action on the other plate. This is true, even although it were poſſible (which we think it is not) to form a clear notion of the free paſſage of this material atmoſphere in an inſtant, and this without any diminution of its quantity, and conſequently of its action, by the diſplacement of ſo much of it by the ſolid matter of the body which it penetrates. Yet without this undiminiſhed action of the electrified plate on the fluid, and on the matter, beyond the glaſs, and on the canal by which its fluid may be driven off into the general maſs—no ſuch accumulation can take place; and if the phenomena of the Leyden phial are agreeable to the reſults of the Æpinian hypotheſis, all explanation by atmoſpheres muſt be abandoned. Indeed when the partiſans of the atmoſpheres attempt to explain their conceptions of them, they do not appear to differ from what are called *ſpheres of activity* a phraſe firſt uſed by Dr Gilbert of Colcheſter, in his celebrated work *De Magnete et Corporibus Magneticis*): and ſpheres of activity will be found nothing more than a figurative expreſſion of ſome indiſtinct conception of *action in every direction*. When we uſe the words *attraction* and *repulſion*, we do not ſpeak a whit more figuratively than when we uſe the general word *action*. Theſe terms are all figurative, only *attraction* and *repulſion* have the advantage of ſpecifying the *direction* in which we conceive the *action* to be exerted.

It therefore becomes ſtill more intereſting to the philoſopher to compare the phenomena of CHARGED GLASS with the Æpinian theory. They afford an *experimentum crucis* in the queſtion about electric atmoſpheres.

151
Phenomena of charged glaſs explained.

Let G (fig. 28.) repreſent the end of a prime conductor, furniſhed with Henley's electrometer. Let AB repreſent a round plate of tinfoil, paſted on a pane of glaſs which exceeds the tinfoil about two inches all round. The pane is fixed in a wooden foot, that it may ſtand upright and be ſhifted to any diſtance from the conductor. DF repreſents another plate of the ſame dimenſions as AB, in the centre of which is a wire EN, having a ſmall ball on the end N, to which is attached a Canton's electrometer. This wire paſſes through the wooden ball O, faſtened to the inſulating ſtand

ELECTRICITY. PLATE XXV.

Fig. 20.

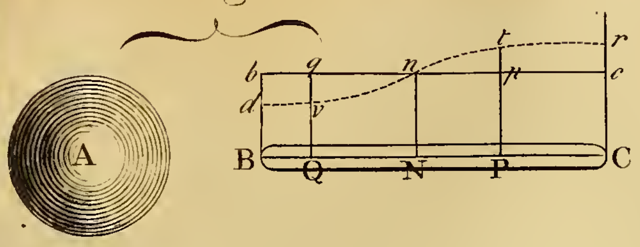


Fig. 24.

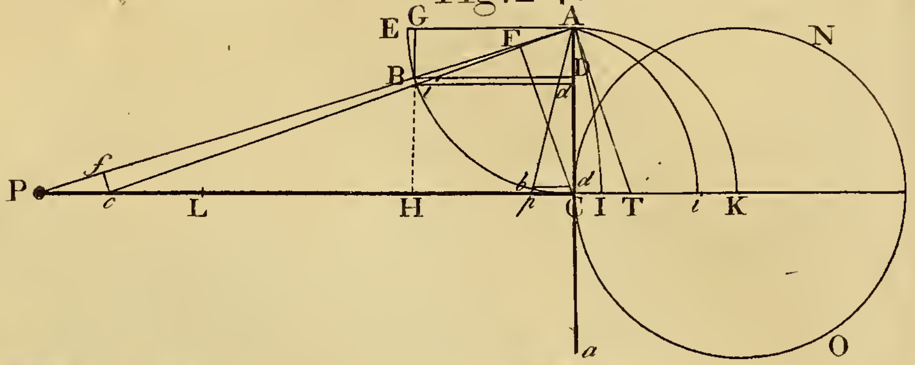


Fig. 21.

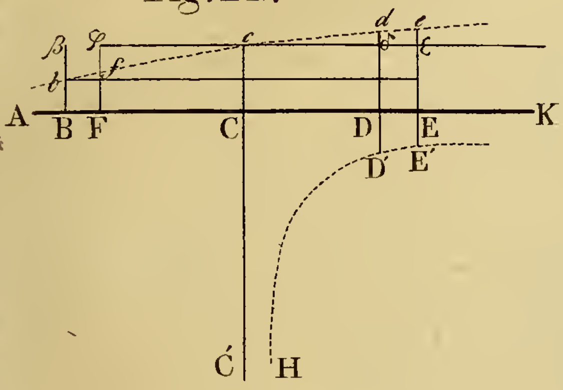
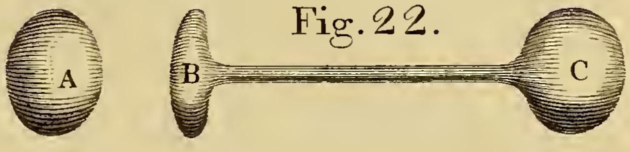


Fig. 22.



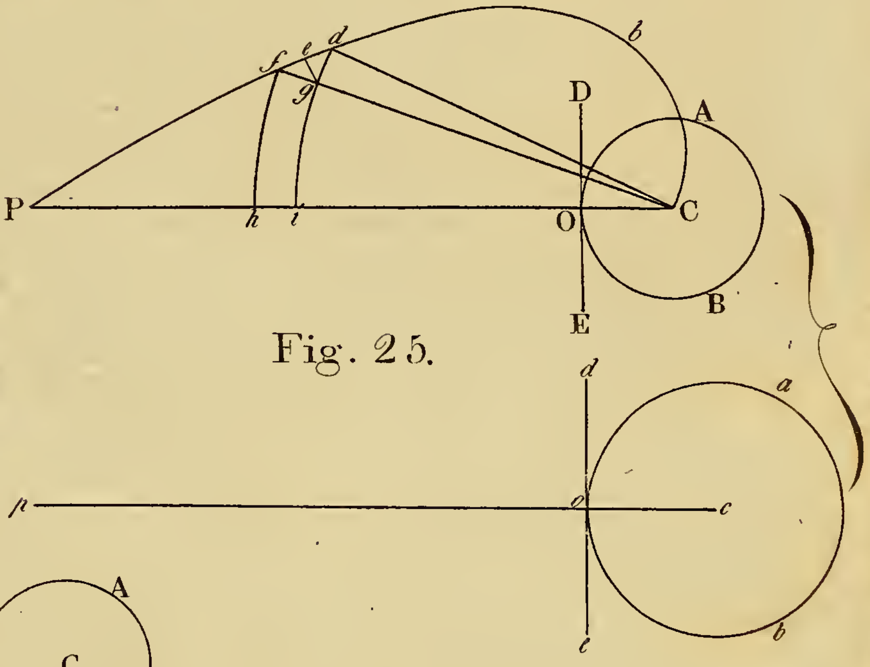


Fig. 25.

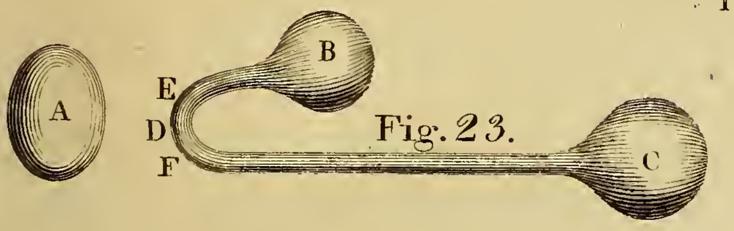


Fig. 23.

Fig. 26.

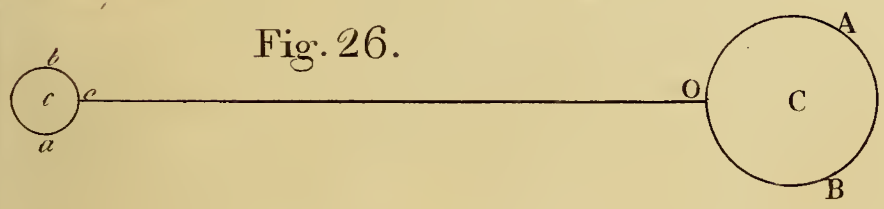
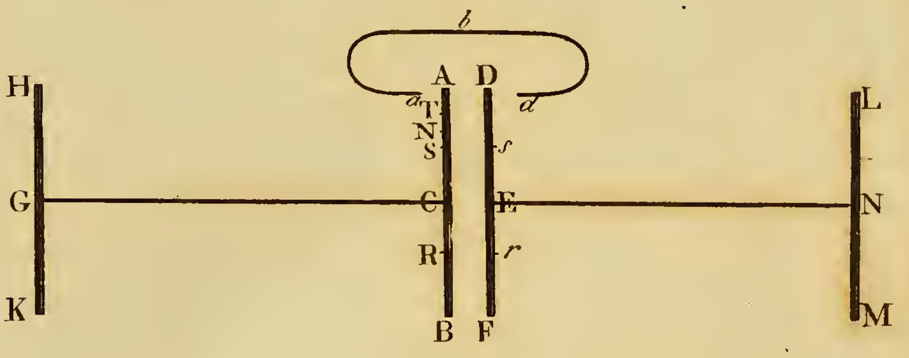
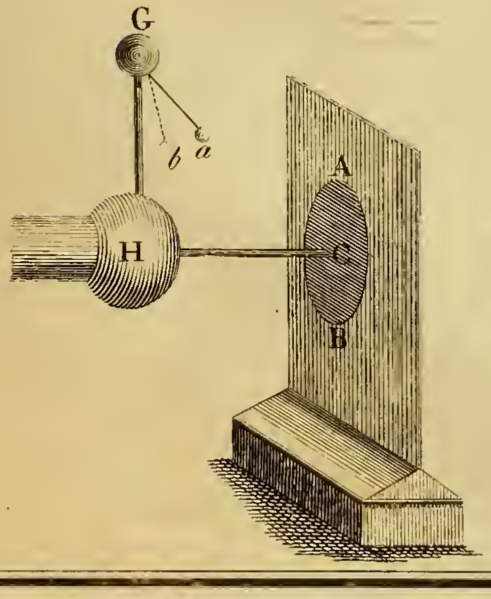


Fig. 27.





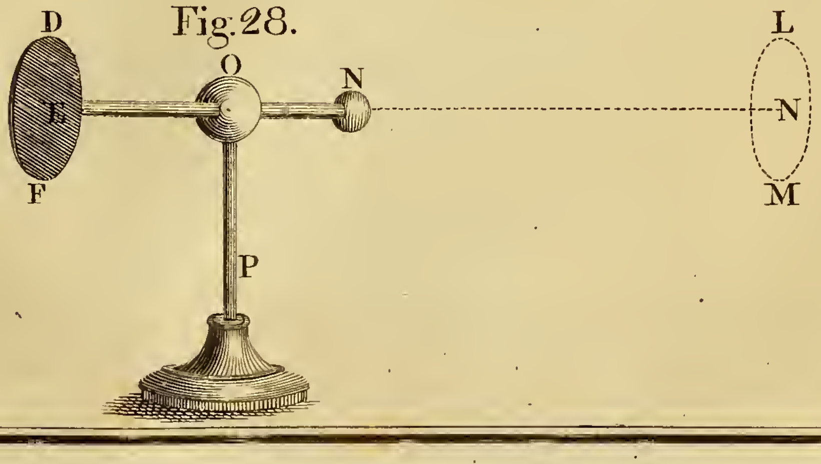


Fig. 28.

I. Draper sc.

ſtand P. The glaſs pane muſt be very clean, dry, and warm. Connect the conductor G with AB by a wire reaching to the centre C. Turn the cylinder of the electrical machine ſlowly, till the electrometer riſe to 30° or 40°, and note the number of turns. Take off the electricity, and having taken away the connecting wire GC, turn the machine again till the electrometer riſe to the ſame height. The difference in the number of turns will give ſome notion of the expenditure of fluid neceſſary for electrifying the plate of tinfoil alone. This will be found to be very trifling when the electricity is in ſo moderate a degree. It is proper, however, to keep to this moderate degree of electrification, becauſe when it is much higher, the diſſipation from the edges of the plate is very great. Replace the wire, and again raiſe the electrometer to 30°. Now bring forward the plate DF, keeping it duly oppoſite and parallel to AB, and taking care not to touch it. It will produce no ſenſible change on the poſition of the electrometer till it come within four or three inches of the glaſs pane; and even when we bring it much nearer (if a ſpark do not fly from the glaſs pane to DF), the electrometer HG will ſink but two or three degrees, and the electrometer at N will be little affected. Now remove the plate DF again to the diſtance of two or three feet, and attach to its ball N a bit of chain, or ſilver or gold thread, which will trail on the table. Again, raiſe the electrometer, to 30°, and bring DF gradually forward to AB. The electrometer HG will gradually fall down, but will riſe to its former height, if DF be withdrawn to its firſt ſituation. It is ſcarcely neceſſary to ſhew the conformity of this to the theory contained in n° 134, 135, &c. As the plate DF approaches, the redundant fluid in AB acts on the fluid in DF, and drives it to the remote end of the wire EN, as was ſhewn by the divergency of the balls at N; and then an accumulation begins in AB, and the electrometer HG falls, in the ſame manner as if part of the fluid in the prime conductor were communicated to AB. When DF communicates with the ground, the electrometer at N cannot ſhew any electricity, but much more fluid is now driven out of DF, in proportion as it is brought nearer to AB. Inſtead of connecting AB immediately with the prime conductor, let the wire GC have a plate at the end G, of the ſame dimenſions as AB, having an electrometer attached to the ſide next to AB. Let this apparatus of two plates be electrified any how, and note the divergency of the electrometer at H, before DF, communicating with the ground, is brought near it, and then attend to the changes. We ſhall find the divergency of this electrometer correſpond with the diſtance of DF very nearly as the theory requires.

152 State of the coatings.

While the plates AB and DF are near each other, eſpecially when DF communicates with the ground, if we hang a pith-ball between them by a ſilk thread, it will be ſtrongly attracted by the plate which is neareſt to it, whether DF or AB; and having touched it, it will be briſkly repelled, and attracted by the glaſs pane, which will repel it after contact, to be again attracted and repelled by DF; and thus bandied between the plates till all electricity diſappear in both, the electrometer attached to H deſcending gradually all the while.

153 As all theſe phenomena are more remarkable in proportion as the plates are brought nearer, they are moſt of all when DF is applied cloſe to the glaſs pane. And if, in this ſituation, we take any accurate method for meaſuring the intenſity of the electricity in the plate HG, before the approach of DF, we ſhall find the diminution, occaſioned by its coming into full contact with the pane, conſiderably greater than what is pointed out in n° 135. When we employed plates of 12 inches diameter, paſted on a pane one-fortieth of an inch in thickneſs, we found the diminution not leſs than 199 parts of 200; and we found that it required at leaſt 200 times the revolution of the cylinder to raiſe the electrometer to the ſame height as before. This compariſon is not ſuſceptible of great accuracy, by reaſon of many circumſtances, which will occur to an electrician. But in all the trials we have made, we are certain that the accumulation greatly exceeded that pointed out by the Æpinian theory as improved by Mr Cavendiſh. And we muſt here obſerve, that we found this ſuperiority more remarkable in ſome kinds of glaſs than others, and more remarkable in ſome other idioelectrics. We think that in general it was moſt remarkable in the coarſe kinds of glaſs, provided they were uniformly tranſparent. We found it moſt remarkable in ſome common glaſs which had exfoliated greatly by the weather: but we alſo found that ſuch glaſſes were very apt to be burſt by the charge. The hardeſt and beſt London crown-glaſs ſeemed to accumulate leſs than any other; and a coloured glaſs, which when viewed by reflection ſeemed quite opake, but appeared brown by tranſmitted light, admitted, an accumulation *greatly* exceeding all that we have tried; but it could not be charged much higher without the certainty of being burſt. This diverſity in the accumulation, which may be made in different kinds of glaſs, hinders us from comparing the *abſolute* accumulations aſſigned by the theory with thoſe which experiment gives us. But though we cannot make this compariſon, we can make others which are equally ſatisfactory. We can diſcover what proportion there is between the accumulation in glaſs of the ſame kind, as it may differ in thickneſs and in extent of ſurface. Uſing mirror glaſs, which is of uniform and meaſurable thickneſs, and very flat plates, which come into accurate or equable contact—we found that the accumulation is inverſely as the thickneſs of the plates; but with this exception, that when two plates were uſed inſtead of a plate of double thickneſs, the diminution by the increaſe of thickneſs was not nearly in the proportion of this increaſe. Inſtead of being reduced to one-half, it was more than two-thirds; and in the kind called Dutch plate, the diminution was inconſiderable.

154 Strong attraction between them.

The experiments with the Dutch and other double plates, ſuggeſted another inſtructive and pretty experiment. Obſerving theſe plates to cohere with conſiderable force, it was thought worth while to meaſure it; which was attempted in this manner: Two very flat braſs plates AB, DF (fig. 29.), furniſhed with wires and balls, were ſuſpended, about three inches aſunder, by ſilk threads, as repreſented in the figure. At G was attached a very fine ſilver wire, which hung very looſe between it and the prime conductor, without coming near the table. Another was attached to N, which touched the table. A plate of mirror glaſs was ſet between them, as ſhewn by QR. When this apparatus was electrified, the threads of ſuſpenſion immediately began to deviate from the perpendicular, and the plates to approach the glaſs pane and each other. The pane was carefully ſhifted, ſo as to be kept in the exact middle between them. This reſult ſhewed very plainly the preſſure of the fluid on one of the plates, and the mutual attraction of the redundant matter and redundant fluid. This increaſed as the accumulation increaſed; and it was attempted to compare the attraction with the accumulation, by comparing the deviation of the ſuſpending threads with that of the electrometer attached to the prime conductor; but we could not reconcile the ſeries (which, however, was extremely regular) with the law of electric action. This harmony was probably diſturbed by the force employed in raiſing the ſilver wires. When more flexible ſilver threads were uſed, much was loſt by diſſipation from the roughneſs of the thread. We did not think of employing a fine flaxen thread moiſtened: but, indeed, an agreement was hardly to be expected; becauſe theory teaches us, that the diſtribution of the redundant fluid in AB will be extremely different from the diſtribution of the redundant matter in DF, till the plates come very near each other. The accumulation in AB depends greatly on the law of diſtribution, being leſs (with any degree of redundancy) when the fluid is denſer near the centre of the plate. Other circumſtances concurred to diſturb this trial; but the theory was abundantly confirmed by the experiment, which ſhewed the ſtrong attraction arriſing from the accumulation. This was ſo great, that although the plates were only three inches in diameter, and the glaſs pane was $\frac{1}{32}$ of an inch thick, and the threads deviated about 18 degrees from the perpendicular—it required above an ounce weight, hung on the wire EN, to ſeparate the plates from the glaſs.

155
Diſcharge; how it is effected.

The experienced electrician need not be told, that by bringing the two ends of a bent wire in contact with the two plates (firſt touching DF with it) diſcharges the apparatus, and cauſes the plates to drop off from the pane. But he may farther obſerve, that if there be attached to each end of the diſcharging wire a downy feather, and if he firſt bring the end near the plate DF, and obſerve the feather to be not at all, or but a very little, affected, and if he then bend round the other end toward the plate AB, *both feathers* will immediately ſtretch out their fibres to the plates, and cling faſt to them, long before the diſcharging ſpark is ſeen. This is a fine proof of the proceſs of diſcharge, which begins by the induction of electricity on the ends of the diſcharing wire; firſt, negative electricity on the end that approaches A, and, in the ſame inſtant, oppoſite electricities at D and the adjoining end of the wire.

156
Beautiful and inſtructive experiment by Profeſſor Richmann.

The following obſervation of Profeſſor Richmann of St Peterſburgh (the gentleman who fell a ſacrifice to electrical ſtudies by a thunder ſtroke from his apparatus) is extremely inſtructive and amuſing. Let a glaſs pane be coated on both ſides, and furniſhed with a ſmall electrometer attached to the coatings. It is repreſented as if ſeen edgewiſe in fig. 30. Let it be charged poſitively (that is, by redundancy) by the coating AB, while DF communicates with the ground. The electrometer A *a* will ſtand out from the plate, and D *d* will hang down cloſe by its coating, as long as DF communicates with the ground. But as the electricity gradually diſſipates by communication to the contiguous air, the ball *a* will gradually, but very ſlowly, fall down. We may judge of the intenſity of the remaining electricity by the deviation of the electrometer, and we may conceive this deviation divided into degrees, indicating, not angles, but intenſities, which we conceive as proportional to the redundancy or deficiency which occaſion them.

If we take away the communication with the ground, we ſhall obſerve the ball *a* fall down very ſpeedily, and then more ſlowly, till it reach about half of its firſt elevation. The ball *d* will at the ſame time riſe to nearly the ſame height; the angle between the two electrometers continuing nearly the ſame as at firſt. When *d* has ceaſed to riſe, both balls will very ſlowly deſcend, till the charge is loſt by diſſipation. If we touch DF during this deſcent, *d* will immediately fall down, and *a* will as ſuddenly riſe nearly as much; the angle between the electrometers continuing nearly the ſame. Remove the finger from DF, and *a* will fall, and *d* will riſe, to nearly their former places; and the ſlow deſcent of both will again continue. The ſame thing will happen if we touch AB; *a* will fall down cloſe to the plate, and *d* will riſe, &c. And this alternate touching of the coatings may be repeated ſome hundreds of times before the plate be diſcharged. If we ſuſpend a crooked wire *v m u*, having two pith-balls *v* and *u* from an inſulated point *m* above the plate, it will vibrate with great rapidity, the balls ſtriking the coatings alternately; and thus reſtoring the equilibrium by ſteps. Each ſtroke is accompanied by a ſpark.

Theory of it.

All theſe phenomena are not only conſequences of the theory, but their meaſures agree preciſely with the computations deduced from the formulæ in n° 22, 23, 24, accommodated to the caſe by means of n° 135 and 136, as we have verified by repeated trials. But it would occupy much room to trace the agreement here, and would fatigue ſuch readers as are not familiarly converſant with fluxionary calculations. The inquiſitive reader will get full conviction by peruſing Æpinus's Eſſay, Appendix i. A very diſtinct notion may be conceived of the whole proceſs, by ſuppoſing that in a minute AB loſes $\frac{1}{10}$th of the unbalanced redundancy actually in it, and conſequently diminiſhes as much in its action. It will be proved afterwards, that the diſſipations in equal times are really in proportion to the ſuperficial repulſions then exerted. We may alſo ſuppoſe, that the action of the redundant fluid, or redundant matter, in either coating, on the external fluid contiguous to it, is to its action on the fluid contiguous to the other coating in the conſtant proportion of 10 to 9. We ſelect this proportion for the ſimplicity of the computation. Then the difference of theſe actions is always $\frac{1}{10}$th of the full action on the fluid contiguous to it. This is alſo an exact ſuppoſition in ſome particular caſe, depending on the breadth of the coating and the thickneſs of the pane.

Now, let the primitive unbalanced repulſion between AB and the contiguous fluid of the electrometer be 100, while DF communicates with the ground. The ball *a* will ſtand at 100; the ball *d* will hang touching DF. Then *a*, by loſing $\frac{1}{10}$th, retains only 90, and would ſink to 90°: But as this deſtroys the equilibrium on the other ſide, fluid will enter into DF, ſo as to reduce the deficiency $\frac{1}{10}$th. Therefore nine degrees of fluid will enter; and its action on *a* will be the ſame as if $\frac{9}{10}$ths of 9, or 8, 1 had been reſtored to AB. Therefore *a* will riſe from 90 to 98,1; or it will ſink in one minute from 100 to 98,1.

But if we have cut off the communication of DF with the ground, this quantity of fluid cannot come into DF; and the quantity which really comes into it from the air will be to that which eſcapes from A as the attraction on the ſide of DF to the repulſion on the ſide of AB. By the diminution of the repulſion $\frac{1}{10}$th, and the want of 9 degrees of fluid in DF to balance it, DF acquires an attraction for fluid, which may be called 9. Therefore, ſince $\frac{1}{10}$th of the primitive repulſion of AB has diſſipated 10 meaſures of fluid in the minute, the attraction of DF will cauſe it to acquire $\frac{1}{10}$th of 9, or 0,9 from the air in the ſame minute. At the end of the minute, therefore, there remains an unbalanced attraction for fluid = 8,1; and conſequently an unbalanced repulſion between the redundant matter in DF, and that in the ball *d*. Therefore *d* will riſe to 8,1. But *a* cannot now be at 98,1; becauſe DF has not acquired 9 meaſures of fluid, but only $\frac{9}{10}$ths of one meaſure. Therefore *a*, inſtead of riſing from 90 to 98,1, will only riſe to 90 + $\frac{9}{10}$ths × $\frac{9}{10}$ths; that is, to 90,81.

At the cloſe of the minute, therefore, *a* is at 90,81, and *d* is at 8,1, and their diſtance is 98,91. In the next minute, AB will loſe $\frac{1}{10}$th of the remaining unbalanced electricity of that ſide, and DF will now acquire a greater proportion than before; becauſe its former unbalanced attraction gets an addition equal to $\frac{9}{10}$ths of the loſs of AB. This will make a larger compenſation in the action on *a*, and *a* will not fall ſo much as before. And becauſe in the ſucceeding minutes the attraction of DF for fluid is increaſing, and the repulſion of AB is diminiſhing, the compenſation in the action on *a*, by the increaſed attraction of DF, continues to increaſe, and the deſcent of *a* grows continually ſlower; conſequently a time muſt come, when the repulſion of AB for fluid is to the attraction of DF for it, nearly in the proportion of 10 to 9. When this ſtate obtains, *d* will riſe no more; becauſe the receipt of fluid by DF, being now $\frac{9}{10}$ths of the loſs by AB, it will exactly compenſate the additional attraction of DF for fluid, occaſioned by that loſs. The next loſs by AB not being ſo great, and the next receipt by DF continuing the ſame, by reaſon of its undiminiſhed attraction, there will be a greater compenſation in the action on *a*, which will prevent its deſcending ſo faſt; and there will be more than a compenſation for the additional attraction of DF for fluid: that is, the fluid which has now come into DF will render it, and alſo the ball *d*, leſs negative than before; and therefore they will not repel ſo ſtrongly. Therefore *d* muſt now deſcend. It is evident, that ſimilar reaſons will ſtill ſubſiſt for the ſlow deſcent of *a*, and the ſlower deſcent of *d*, till all redundancy and deficiency are at an end.

This maximum of the elevation of *d* happens when *a* has deſcended about one-half of its elevation; that is, when the unbalanced repulſion of AB is reduced to about one half. For if one half of the unbalanced fluid be really taken out of AB, and if DF can get no ſupply whatever, it muſt acquire an attraction correſponding to $\frac{9}{10}$ths of this; and if the ſupply by the air be now opened to it, things will go on in the way already deſcribed, till all is diſcharged.

This account of the proceſs is only an approximation; becauſe we have ſuppoſed the changes to happen in a deſultory manner, as in the popular way of explaining the acceleration of gravity. The riſe of *d* is not at an end till the attraction of DF for fluid is to the repulſion of AB as 19 to 20.

But if we interrupt this progreſs in any period of it, by touching DF, we immediately render it neutral, and *d* falls quite down, in conſequence of receiving a complete ſupply of fluid. But this muſt change the ſtate of AB, and cauſe it to riſe $\frac{9}{10}$ths of the deſcent of *d*. As *a* and *d* were nearly at an equal height before DF was touched, it is plain that *a* will riſe to nearly twice its preſent height; after which, the ſame ſeries of phenomena will be repeated as ſoon as the finger is removed from DF.

If, inſtead of touching DF, we touch AB, the ſame things muſt happen; *a* muſt fall down, and *d* muſt riſe to nearly twice its preſent height, and all will go on as before, after removing the finger. Laſtly, if inſtead of allowing either ſide to touch the *ground* alternately, we only touch it with a *ſmall inſulated body*, ſuch as the wire with the balls *v* and *u*, the ball attached to the ſide touched ſinks, till the electricity is ſhared between the coating and the wire with balls. The ball attached to the other coating riſes $\frac{9}{10}$ths of the ſinking of the firſt ball. The crooked wire ball is now repelled by the coating which it touched, and the other ball is brought near to the other coating, and muſt be attracted by it, becauſe the electricities are oppoſite. This operation evidently tends to transfer the redundant fluid *by degrees* to the ſide where it is deficient. It needs no explanation. We ſhall only mention a thing which we have always obſerved, without being able to account for it. The vibration of the wire acquires a certain rapidity, which continues for a long while, and ſuddenly accelerates greatly, and immediately afterwards ceaſes altogether.

This pretty experiment of Profeſſor Richmann will be found very inſtructive; and will enable us to underſtand the operation of the electrophorus, and to ſee the great miſtake of thoſe who ſay that it is perfectly ſimilar to a diſcharged glaſs plate.

157
Electric action *e diſtanti* demonſtrated.

Thus, then, we ſee, that all the claſſes of phenomena, connected with attraction and repulſion, are preciſely ſuch as would reſult from the action of a fluid ſo conſtituted. The complete undiminiſhed action of the cauſe of thoſe phenomena on the other ſide of the interpoſed non-conductor of that cauſe is demonſtrated, and all explanation by the mechanical action of material elaſtic atmoſpheres of variable denſity muſt be abandoned, and the infinitely ſimpler explanation by the attractive and repulſive forces of the fluid itſelf muſt be preferred.

So happily does the Franklinian theory of poſitive and negative electricity explain the phenomena, when a ſuitable notion is formed of the manner of action of this fluid. We cannot but think that this is attained, when, to the general doctrine of Æpinus, we add the ſpecification of the law of action, ſo fully verified by the experiments of Mr Coulomb, which are in the hands of the public; and are of that ſimple nature, that pendent of all theory. Now electrify a jar, or a row of equal jars, to the ſame degree with the firſt, and communicate the charge to a coated mirror plate, diſcharging the plate after each communication, till the electrometer reaches the degree which indicates one-half. This ſhews how often the charge of the plate is contained in that of the jar or row of jars.

Let the charge of the plate be to that of the jars as x to 1. Then, by each communication, the electricity is diminiſhed in the proportion of $\overline{1+x}$ to 1. If m communications have been made, it will be reduced in the proportion of $\overline{1+x}^m$ to 1. Therefore $\overline{1+x}^m = 2$, and $1+x = \sqrt[m]{2}$, and $x = \sqrt[m]{2} - 1$.

When x is ſmall in proportion to 1, we ſhall be very near the truth, by multiplying the number of communications by 1,444, and ſubtracting 0,5 from the product. The remainder ſhews how often the charge of the plate is contained in that of the jars, or $\frac{1}{x}$.

Thus may the perfect equality of two jars be aſcertained; and the one which exceeds, on trial, may be reduced to equality by cutting off a little of the coating. An electrician ſhould have a pair of ſmall jars or phials ſo adjuſted. It will ſerve to diſcover in a minute or two the mark of one-half electricity for any electrometer, and for any degree; as alſo for meaſuring jars, batteries, ſhocks, &c. much more accurately than any other method: becauſe ſuch phials, conſtructed as we ſhall deſcribe immediately, may be made ſo neutral, and ſo retentive, that the quantity which diſſipates during the handling becomes quite inſignificant in proportion to the quantity remaining; whereas, in all experiments with electrometers, conſtructed with the moſt curious attention, the diſſipations are great in proportion to the whole, and are capricious.

164 It was chiefly by this method that the writer of this article, having read Mr Cavendiſh's paper, compared the meaſures given by experiment with thoſe which reſult from an action in the inverſe duplicate ratio of the diſtance. When the charges were moderate, the coincidence was perfect; when the charges were great, the large plates contained a little more. This is plainly owing to their being leſs diſpoſed to diſſipate from the edges.

165
Maxims for conſtructing jars, batteries, &c.

We may now follow with ſome confidence the practical maxims deducible from the theory for the conſtruction of this accumulating apparatus. The theory preſcribes a very conducting coating, in cloſe and uninterrupted contact; It preſcribes an extenſive ſurface, and a thin plate of idio-electric ſubſtance. Accordingly all theſe are in fact attended by a more powerful effect. Metal is found to be far preferable to water, which was firſt employed, having been ſuggeſted by the original experiments of Gray, Kleiſt, and Cunæus. A continuous plating is preſcribed, in preference to ſome methods commonly practiſed; ſuch as filling the jar with braſs duſt, or gold leaf, or covering its ſurface with filings ſtuck on with gum water, or coating the inſide with an amalgam of mercury and tin. This laſt appears, by reflection from the outſide, to give a very continuous coating; but if we hold the jar between the eye and the light, we may perceive that it is only like the covering with a cobweb. Yet there are caſes where theſe imperfect coatings only are practicable, and ſome rare ones where they are preferable. In the medical exhibition of electricity, where the purpoſe intended is ſuppoſed to require the transfuſion of a great quantity of the electric fluid, any thing that can diminiſh the irritating ſmartneſs of the ſpark is deſirable. This is greatly effected by thoſe imperfect coatings. Small ſhocks, which convey the ſame quantity of fluid with the ſharp pungent and alarming ſpark from a large ſurface, are quite ſoft and inoffenſive, greatly reſembling the ſpaſmodic quivering, ſometimes felt in the lip or eye-lid, and will not alarm the moſt fearful patient.

Hint for medical exhibition of electricity.

166
How to prevent the burſting of jars by high charges.

Cloſe contact of the metallic coating is obſerved to increaſe the effect of the charge. But it is alſo found, that it greatly increaſes the riſk of burſting the glaſs by ſpontaneous diſcharge through its ſubſtance. An experienced electrician (we think it is Mr Brookes of Norwich) ſays, that ſince he has employed paper covered with tinfoil, with the paper next the glaſs, inſtead of the foil itſelf, he has never had a jar burſt; whereas the accident had been very frequent before. The theory juſtifies this obſervation. Paper is an imperfect conductor, even when ſoaked with flour paſte; and the transfuſion, though rapid, is not inſtantaneous nor deſultory, but begins faintly, and ſwells to a maximum. It operates on the glaſs, like gradual warming inſtead of the ſudden application of great heat.

167
Very curious obſervation by Mr Cuthbertſon.

Mr Cuthbertſon, an excellent artiſt in all electrical apparatus, and inventor of the beſt air-pump, has made a curious obſervation on this ſubject. He ſays that he has uniformly obſerved, that jars take a much greater charge (nearly one-third), if the inſide be conſiderably damped, by blowing into it with a tube reaching to the bottom (*Nicholſon's Journal, March* 1799).—We muſt acknowledge, that we can form no diſtinct conception of what Mr Cuthbertſon calls *an undulation of the elaſtic atmoſphere*. We do not know whether he means that the atmoſphere is actually undulating as water, or as air in the production of ſound, its parts being in a reciprocating motion; or whether he only means that this atmoſphere conſiſts of quieſcent ſtrata, alternately denſer and rarer. Nor can we form any notion how either of theſe undulations contributes to the exploſion, or prevents it. We are really but very imperfectly acquainted with that part of the ſcience which ſhould determine the preciſe accumulation that produces the deſultory transference. We mentioned one neceſſary conſequence of the action inverſely as the ſquare of the diſtance, which has ſome relation to this queſtion, *viz.* that a particle, making part of a ſpherical ſurface, is twice as much repelled when it has juſt quitted the ſurface as when it made part of it, provided its place be immediately ſupplied. And another circumſtance has been frequently mentioned, *viz.* that a greater, and perhaps much greater, force is neceſſary for enabling a particle of fluid to quit the laſt ſeries of particles of the ſolid matter than for producing almoſt any conſtipation. But we are not certain that theſe circumſtances are of ſufficient influence to explain the whole of the event. *Valeant quantum valere poſſint.* Yet we are of opinion that Mr Cuthbertſon has aſſigned the true cauſe, namely, the imperfect coating of the inſide of the glaſs. When we come to the explanation of the eſcape of electricity along imperfect conductors, we hope that it will appear, that the diſpoſition to eſcape muſt be greatly diminiſhed by a charge, which diſpoſes the fluid ſo, that in no place the conſtipation is remarkably greater than in another part very near it, and the denſity changes every where ſlowly.

168
Beſt forms for jars, &c.

With reſpect to the form of the coated glaſs, the theory preſcribes that which will occaſion ſuch a diſtribution of the electric fluid as ſhall make its repulſion for the fluid in the canal which connects it with the prime conductor as little as poſſible. In this reſpect, it would ſeem that a plate is the beſt, and a globe the worſt: but if both are very thin, the difference cannot be conſiderable. Our experience, however, ſeems to indicate the oppoſite maxim as the moſt proper. We have uniformly found a globe to be far preferable to a plate of the ſame thickneſs, and that a plate was generally the weakeſt form. It muſt be owned, that we have not yet been able to aſcertain by the theory what is the exact diſtribution of the redundant fluid in a plate. In a ſphere, it muſt be uniformly ſpread over the ſurface. We muſt alſo aſcribe part of the inferiority of the plate to its greater tendency to diſſipation from the edges. If a plate be coated in a ſtar-like form, with ſlender projecting points, we ſhall obſerve them luminous in the dark, almoſt at the beginning of the accumulation; and the plate will diſcharge itſelf by theſe points, over the uncoated part, before it has attained any conſiderable ſtrength. Thoſe forms are leaſt expoſed to this deterioration which have the leaſt circumference to the ſame quantity of ſurface. We have always found, that a ſquare coating will not receive a more powerful charge without exploding than a circular one of the ſame breadth, although it contains a fourth more ſurface; and this although any viſible eſcape from the angles be prevented by covering the outline with ſealing-wax. Of all forms, therefore, a globe, with a very narrow, but long neck, is the moſt retentive. But it is very difficult to coat the inſide of ſuch a veſſel. The balloons uſed in chemical diſtillations make excellent jars, and can be eaſily coated internally when the neck will admit the hand. The thinneſt of tinfoil may be uſed, by firſt paſting it on paper, and then applying it either with the foil or the paper next the glaſs. It ſhould be cut into guſſets, as in the covering of terreſtrial globes; and they ſhould be put on overlapping about half an inch. The middle of the bottom is then coated with a circular piece. The great bottles for holding the mineral acids are alſo good jars, but inferior to the balloons, becauſe they are very thick in the bottom, and for ſome diſtance from it. A box of balloons contains more effective ſurface than an equal box of jars of the ſame diameter and height of coating.

169
Compendious battery.

The moſt compendious battery may be made in the following manner: Chooſe ſome very flat and thin panes of the beſt crown glaſs, coat a circle (*a b c d*), (fig. 31.) in the middle of both ſurfaces, ſo as to leave a ſufficient border uncoated for preventing a ſpontaneous diſcharge; let each of them have a narrow ſlip of tinfoil *a* reaching from the coating to the edge on one ſide, and a ſimilar ſlip *c* leading to the oppoſite edge on the other ſide. Lay them on each other, ſo that the ſlips of two adjoining plates may coincide. Connect all the ends of theſe ſlips on one ſide together by a ſlip of the ſame foil, or a wire which touches them all. Then, connecting one of theſe collecting ſlips with the prime conductor, and the other with the ground, we may charge and diſcharge the whole together. If the panes be round, or exact ſquares, we may employ as few of them together as we pleaſe, by ſetting the whole in an open frame, like an old-faſhioned plate-warmer; and then turning the ſet which we would employ together at right angles to the reſt. This evidently detaches the two parcels from each other. This battery may be varied in many ways; and if the whole is always to be employed together, we may make it extremely retentive, by covering the uncoated border of the plate with melted pitch, and, while it is ſoft, preſſing down its neighbour on it till the metallic coatings touch. For greater variability this may be done in parcels of the whole.

170
Another.

On the ſame principle, a moſt compendious battery may be made by alternate layers of tinfoil and hard varniſh, or by coating plates of very clear and dry Muſcovy glaſs. But theſe muſt be uſed with caution, leſt they be burſt by a ſpontaneous diſcharge; in which caſe we cannot diſcover where the flaw has happened. They make a ſurpriſing accumulation, without ſhewing any vivid electricity.

171
Portable jar.

We have made a very fine electric phial for carrying about, by forming tin-plate (iron plate tinned) into ſomewhat of a phial ſhape, with a long neck. We then covered this with a coating of fine ſealing-wax, about $\frac{1}{10}$th of an inch thick, quite to the end of the neck, and coated the ſealing-wax, all but the neck, with tinfoil. It is plain that the ſealing-wax is the coated idio-electric, and that the tin-plate phial ſerves for an inner coating and wire. The diſſipation is almoſt nothing if the neck be very ſmall; and it only requires a little caution to avoid burſting by too high a charge. Even this may be prevented by coating the ſealing-wax ſo near to the end of the neck, that a ſpontaneous diſcharge muſt happen before the accumulation is too great.

172
Importance of a cloſe diſcharge.

It is well known that the diſcharge happens when the diſcharging balls are at a conſiderable diſtance from each other; therefore only as much is diſcharged as correſponds to that diſtance. This is one cauſe of the reſiduum of a diſcharge which ſometimes is pretty conſiderable. Some experiments require the very utmoſt force of the charge. It is therefore proper to make the diſcharge as cloſe and abrupt as poſſible. But the moſt rapid approach that we can make of the diſcharger is nothing in compariſon with the velocity with which the fluid ſeems to fly off, and will therefore have but ſmall influence in making a more inſtantaneous and complete diſcharge. Theory points out the following method: Let a very thick plate of glaſs (half an inch), of ſeveral inches diameter, be put between the diſcharging balls, which ſhould, in this caſe, be ſmall, and let theſe balls be ſtrongly preſſed againſt it by a ſpring. While the charge is going on, a very ſmall part of the glaſs plate, round the points of contact, will receive a weak and uſeleſs charge; but this will not hinder the battery from acquiring the ſame intenſity of charge. When this is completed, let the intervening glaſs plate be briſkly withdrawn. The diſcharge will begin with an intenſity which is unattainable in the ordinary manner of proceeding.

173
Lateral exploſion.

Much has been ſaid of the lateral exploſion. It appears, that in ſome of the prodigious transferences of electricity that have taken place in the diſcharge of great ſurfaces through wires barely ſufficient to conduct them, flaſhes diſtance between the redundant and deficient ſtratum is leſs than the thickneſs of the glaſs; and this, perhaps, in an unknown proportion.

This precious experiment of Dr Franklin was repeated by every electrician, and varied in a thouſand ways. No philoſopher has carried this reſearch farther than Beccaria; and he has given ground for a moſt important diſcovery in the mechanical theory, namely, that the charged glaſs has ſeveral ſtrata, of inconceivable thinneſs, alternately redundant and deficient in electric fluid; and that by continuing the electrification, theſe ſtrata penetrate deeper into the glaſs, and probably increaſe in number. We have not room here to give even an account of his experiments, and muſt refer the philoſophical and curious reader to that part of his valuable Treatiſe where he treats of what he calls *vindicating* or *recovering electricity*; as alſo to a paper by Mr Henley in Phil. Tranſ. for 1766, giving account of experiments on Dutch plates by Mr Lane. The general form of the experiment is this. He puts two plates together; he coats the outer ſurfaces, and charges and diſcharges them as one thick plate. Their inner touching ſurfaces are found ſtrongly electrical after the diſcharge, having oppoſite electricities, and changing theſe electricities, by repeated ſeparations and replacings, in a way ſeemingly very capricious at firſt ſight, but which the attentive reader will find to be according to fixed laws, and agreeably to the ſuppoſition that the ſtrata gradually ſhift their places within the glaſs, very much reſembling what we obſerve on a long glaſs rod which we would render electric by induction. In this caſe, as was obſerved in nº 57. there are obſerved more than one neutral point, &c.

178 Mr Cavendiſh endeavours to give us ſome notion of the diſpoſition of the fluid in the ſubſtance of the glaſs in the following manner: Having ſeparated the coated plate from the machine and from the ground, ſuppoſe a little of the redundant fluid in B β δ D (fig. 33.) equal to the fluid wanting in E ε φ F. If we now ſuppoſe all the redundant fluid to be lodged in *b β δ d*, and *e ε φ f* to hold all the redundant matter, and the two coatings to be in their natural ſtate, a particle *p*, placed in the middle of the ſurface *b d*, will be nearly as much attracted by *ε e f φ* as it is repelled by *b β δ d* (exactly ſo if the plates were infinitely extended); and if the coating be removed, keeping parallel and oppoſite to the ſurface that it quits, there will be very little, if any, tendency to fly from the glaſs to the coating: there will rather be ſome diſpoſition in the fluid to quit the coating and fly to the glaſs; becauſe the repulſion of *b β δ d* is more diminiſhed than the attraction of *ε e f φ* (nº 42.). But the difference will be very ſmall indeed. (*N. B.* the reſult would be very different if electric action followed a different law. Were it as $\frac{1}{d^3}$, the coating would be much overcharged; and were it as $\frac{1}{d}$, it would be very much undercharged). Now the fact is, that when the coating is carefully removed, it is poſſeſſed of very little electricity, not more than may reaſonably be ſuppoſed to run into it by bringing away one part before another. It is impoſſible to keep it mathematically parallel.

Hence we may conclude that the greateſt part of the redundant fluid is lodged in the glaſs if the plates be thin, and the redundant fluid bear but a ſmall proportion to the natural quantity. Similar reaſoning ſhews that the greateſt part of the deficiency is in the other ſide of the glaſs; and that therefore the coatings are very nearly in their natural ſtate, and merely ſerve the purpoſe of conducting.

We have employed coatings of conſiderable thickneſs, having holes through them, oppoſite to which was ſome gold leaf of the heavieſt ſort, and almoſt free of cracks. We have examined the ſtate of the bottom of thoſe pits in Mr Coulomb's manner, and always found them void of electricity.

179 Conjecture about the burſting of jars.

Thus we learn that glaſs, and probably all other electrics, acquire redundant and deficient ſtrata as well as the moſt perfect conductors, at the ſame time that they may be impervious to the fluid; and we get ſome mode of conceiving how the rupture happens by a ſtrong charge. This may very probably happen when the ſtrata have formed, in alternate order, ſo deep in the glaſs, that a ſtratum, in which the fluid is crowded cloſe together, may become contiguous to one deprived altogether of fluid. We cannot, however, ſay with confidence, what *ſhould* be the effect of this ſtate of things; or of one conſtipated ſtratum coming in contact with another.

This view of the condition of charged glaſs explains (we think) ſeveral phenomena which ſeem not well underſtood by electricians.

180 Several phenomena explained.

The reſiduum of a diſcharge is frequently owing to a charge extending beyond the coating, where the action is conſiderably irregular, or different from what it would be if the plates were infinitely extended. This *outline* charge is taken up by the coated part after a very little while, and may again be diſcharged. But it alſo frequently ariſes from another ſtratum (much thinner, as it will always be) than the exterior one, coming to the ſurface ſome time after the firſt diſcharge, and being now in a condition for being diſcharged. It explains the ſparkling that is perceived in *ſucceſſion* between the parts of a jar that is coated in ſpots, during the charge, and the very ſenſible reſiduum of the charge of ſuch a veſſel. It explains the phenomena of Beccaria's *Electricitas Vindex* (ſee Electricity, *Encycl.* § 48.), and the great difference that may be found in the different kinds of glaſs in this reſpect. It explains the great difference between the ſenſation occaſioned by a ſpark from a perfectly conducting ſurface of conſiderable extent, and that occaſioned by a ſhock, which conveys the ſame quantity of fluid accumulated in a ſmall ſurface of glaſs. The diſcharge of the firſt is almoſt inſtantaneous, while that of the laſt requires a ſmall moment of time, and is therefore leſs deſultory and abrupt. The one is pungent and ſtartling; but the other is ſofter in the firſt inſtant, and ſwells to a maximum. Therefore, in the medical employment of electricity, when the purpoſe is to be effected by the transfuſion of a great quantity of electric fluid, we ſhould recommend very ſmall ſhocks from a very large ſurface of coated glaſs, very faintly electrified, in place of ſtrong ſparks. Patients of irritable conſtitutions are frequently alarmed by the quickneſs and pungency of ſtrong ſparks: but if the balls of Lane's ſhock-meaſurer be ſet ſo cloſe as to give four or five ſhocks in each turn of a ſeven inch cylinder, the ſhocks are not even diſagreeable. The balls ſhould be made of fine cupelled ſilver: in which caſe, the ſurface will never be hurt by the greateſt diſcharge; whereas the diſcharge of four ſquare feet of coated glaſs will raiſe ſuch a roughneſs on the ſurface of braſs as will cauſe it to ſpatter, and deſtroy entirely the regularity of the expenditure of fluid. The ſame conſideration ſhould make us prefer a jar coated internally with amalgam. This cobweb coating gives a greater ſoftneſs to the ſhock. Laſtly, we ſee why a powerful and permanent electricity was not produced in the tube filled with melted ſealing-wax, and treated as mentioned in nº 101. The redundancy and deficiency intended to be produced could only be ſuperficial. And becauſe the wax cooled by degrees from the ſurface to the axis, and the wax is a conductor while liquid, it muſt have taken a charge at laſt; and therefore muſt appear but faintly electrical.

181 This account of the ſtate of charged glaſs promiſes us ſome aſſiſtance in our attempts to conceive what paſſes in the excitation of glaſs by friction. It appears from Beccaria's experiments, that the redundant fluid is lodged in the ſame manner in both caſes; for by rubbing one ſide of a glaſs tumbler, while points were preſented to the oppoſite ſurface, and were connected with a wire that communicated with the ground, he gave it a powerful charge.

182 The quantity of fluid in a body may be exceeding great.

It is obſerved, that when the laminæ of a piece of Muſcovy glaſs are ſeparated, by pulling them aſunder without inſerting any inſtrument between them, they are electrical when ſeparated; one being poſitive, and the other negative. Muſt we not conclude from this, that when conjoined they were in the ſtate of charged glaſs? If we take this view of it, a body may contain a prodigious quantity of electric fluid without exhibiting any appearance of it. Mr Nicholſon found, by a very fair computation from his experiments, that a cubic inch of talc, when ſplit into plates of 0,011 of an inch in thickneſs, and coated with gold leaf, gave a ſhock equal to the emptying 45 conductors, each ſeven inches in diameter and three feet long, electrified ſo that each gave a ſpark at nine inches diſtance. Now, the whole of this was moveable fluid, and no more than what the talc contains when unelectrified: for no more comes into the poſitive ſide than goes out of the negative ſide. Nay, there is no probability that the quantity moveable in our experiments bears a conſiderable proportion to the natural quantity. The quantity of moveable fluid in a man's body is therefore very great: and Lord Mahon is well authoriſed to ſay, that the ſudden diſplacing of this quantity in a *returning ſtroke*, which has been occaſioned by a diſcharge of a cloud in a very diſtant place, is fully adequate to the production of the moſt violent effects. But his Lordſhip has not attended to the circumſtance, that no ſuch diſplacement can happen. The accumulation that can be made in the human body is only ſuperficial; and therefore, although the whole fluid of a man's body may change its place, it will not change it with the rapidity that ſeems neceſſary for the violent effects of electricity, except in the very points of communication with the ſurrounding bodies.

183 We have now ſeen in what ſenſe the idio-electrics may be ſaid to be impervious to the electric fluid. It is moved in them only to very ſmall and imperceptible diſtances. When a conſiderable ſtratum is diſcharged, the fluid does not come from the extremity of it to the point of diſcharge through the glaſs, but through the coating. And when alternate ſtrata of redundant fluid and redundant matter are formed, the particles in each ſhift their places very little, moving perpendicularly to the ſtratum.

184 The impermeability of electrics denied by ſome.

Even this degree of obſtruction has been denied by ſome very active electricians, who have multiplied experiments to prove that the fluid paſſes freely through glaſs, and that the theory of coated electrics is totally different from what Franklin imagines. Mr Lyons of Dover has publiſhed a numerous liſt of ſingular experiments, which he has made with this view, with much trouble, and no ſmall expence. They may all be reduced to this: A wire is brought from the outſide of a phial, charged by the knob, and terminates in a ſharp point at a ſmall diſtance from a thin glaſs plate (it is commonly introduced into a glaſs tube, having a ball at the end, and the point of the wire reaches to the centre of the ball); and another wire is connected with the diſcharging rod, and alſo comes very near (and frequently cloſe) to the other ſide of the glaſs, oppoſite to the pointed wire. With this apparatus he obtains a diſcharge; and therefore ſays, that the glaſs is permeable to electricity. But he does not narrate all the circumſtances of the experiment. We have repeated all of them that have any real difference (for moſt of them are the ſame fact in different forms), and we have obtained diſcharges: But they were all very incomplete, except when the glaſs was perforated, which happened very frequently. The diſcharge was never made with a full, bright, undivided ſpark, and loud ſnap; but with ſputtering, and trains of ſparks, continued for a very ſenſible time; and the phial was never deprived of a conſiderable part of its charge: and (which Mr Lyons has taken no notice of) the glaſs is found to be charged, negative on the ſide connected with the poſitive ſide of the phial, and poſitive on the other. This charge was communicated to the glaſs over a pretty conſiderable ſurface round the points immediately oppoſite to the wires. This is quite conformable to the experiments of Dr Franklin and Beccaria, who charged a tumbler by graſping it with the hand, and preſenting the inſide to a point electrified by the prime conductor. The whole experiment is analogous to the one narrated in nº 176.

185 Bars touched like magnets for electricity.

We may conclude our obſervations on coated glaſs with mentioning a curious experiment. A flat ſtick of fine ſealing-wax, warmed till it bent pretty readily, was rendered permanently electrical, with a poſitive and negative pole, in a manner analogous to the double touch of magnets. A ſmall jar was taken, having a hemiſphere on the end of its inſide wire, and another on the end of a ſtiff wire projecting from the outer coating, and then turned up parallel to the inſide wire; ſo that the two hemiſpheres ſtood equally high, and about three inches aſunder. This jar was electrified ſo weakly, as to run no riſk of a ſpontaneous diſcharge. The flat faces of the two hemiſpheres were now applied to the flat ſide of the ſealing-wax, and were moved to and fro along it, overpaſſing both ends about an inch with each hemiſphere. The experiment was very troubleſome; for the phial often diſcharged itſelf along the ſurface of the ſealing-wax, and all was to begin again. But, by continuing this operation till the ſealing-wax grew quite cold and hard, it acquired a very ſenſible electricity, which laſted ſeveral weeks when kept with care; but ſtill it was not much more ſenſible than that of the ſealing-wax, which congealed between two globes oppoſitely electrified.

186 Electrophorus.

After this application of the theory to the phenomena of coated glaſs, it will not be neceſſary to employ much time in its application to the electrophorus. The general propoſitions from n° 14. to 25. and their companions in n° 38—43. will enable us to ſtate with preciſion (when combined with the law of electric action) the actions of every part of this apparatus; and conſiderable aſſiſtance will be derived from a careful conſideration of our analyſis of Profeſſor Richmann's experiment in n° 156. But we muſt content ourſelves with a general, popular view of theſe particulars, which may be ſufficient for making us underſtand what will be the *kind*, and ſomewhat of the *intenſity*, of the action of its different parts.

The electrophorus conſiſts of three parts. The chief part is the cake ABCD (fig. 34.) of ſome electric; ſuch as gum lac, ſealing-wax, pitch, or other reſinous compoſition. This is melted on ſome conducting plate, DCFE, and allowed to congeal; in which ſtate it is found to be negatively electric. Another conducting plate GHBA is laid on it, and may be raiſed up by ſilk lines, or any inſulating handle. We ſhall call ABCD the cake, DCFE the sole, and GHBA the cover.

The general appearances not having been ſo ſcientifically claſſed in the article Electricity as could be wiſhed, we ſhall here narrate them, very briefly, in a way more ſuited to our purpoſe. In comparing the theory with obſervation, it will be proper to make all the three parts of conſiderable thickneſs, and of no great breadth. Although this diminiſhes greatly the moſt remarkable of the actions, it leaves them ſufficiently vivid, and it greatly increaſes the ſmaller changes which are inſtructive in the compariſon. The general facts are,

Phenomena thereof.

1. If the ſole has been inſulated during the congelation of the electric, till all is cold and hard, the whole is found negatively electric, and the finger draws a ſpark from any part of it, eſpecially from the ſole. If allowed to remain in this ſituation, its electricity grows gradually weaker, and at laſt diſappears: but it may be excited again by rubbing the cake with dry warm flannel, or, which is the beſt, with dry and warm cat or hare fur. If the cover be now ſet on the cake by its inſulating handle, but without touching the cover, and again ſeparated from the cake, no electricity whatever is obſerved in the cover.

2. But if it be touched while on the cake, a ſharp pungent ſpark is obtained from it; and if at the ſame time, the ſole be touched with the thumb, a very ſenſible ſhock is felt in the finger and thumb.

3. After this, the electrophorus appears quite inactive, and is ſaid to be *dead;* neither ſole nor cover giving any ſign of electricity. But,

4. When the cover is raiſed to ſome diſtance from the cake (keeping it parallel therewith), if it be touched while in this ſituation, a ſmart ſpark flies, to ſome diſtance, between it and the finger, more remarkably from the upper ſide, and ſtill more from its edge, which will even throw off ſparks into the air, if it be not rounded off. As this diminiſhes the deſired effects, it is proper to have the edge ſo rounded. This ſpark is not ſo ſharp as the former, and reſembles that from any electrified conductor.

5. The electricity of the cover, while thus raiſed, is of the oppoſite kind to that of the cake, or is poſitive.

6. The electricity of the cover while lying on the cake is the ſame with that of the cake, or negative.

7. The appearances n° 2, 3, 4, may be repeated for a very long time without any ſenſible diminution of their vivacity. The inſtrument has been known to retain its power undiminiſhed even for months. This makes it a ſort of magazine of electricity, and we can take off the electricity of the cake and of the cover as charges for ſeparate jars, the cover, when raiſed, charging like the prime conductor of an ordinary electrical machine; and, when ſet on the cake, charging it like the rubber. This cauſed the inventor, Mr Volta, to give it the name of Electrophorus.

8. If the ſole be inſulated before putting on the cover, the ſpark obtained from the cover is not of that cutting-kind it was before: but the ſame ſhock will be felt if both cake and cover be touched together.

9. If the cover be again raiſed to a conſiderable height, the ſole will be found electrical, and its electricity is that of the cake, and oppoſite to that of the cover.

10. After touching both cover and ſole, if the cover be raiſed and again ſet down, without touching it while aloft, the whole is again inactive.

11. If both cover and ſole be made inactive when joined, they ſhew oppoſite electricities when ſeparated, the ſole having the electricity of the cake.

12. If both cover and ſole be made inactive when ſeparate, they both ſhew the oppoſite to the electricity of the cake when joined.

187 Diſpoſition of the fluid thereon.

Let us now attend to the diſpoſition of the electrical fluid in the different parts of the inſtrument in their various ſituations, and to the forces which operate mutually between them. *N. B.* Experiments for examing this inſtrument are beſt made by ſetting the three plates vertically, ſupported on glaſs ſtalks, with leaden feet, to ſteady them. A very ſmall electrometer may be attached to the outer ſurfaces of the cover and ſole.

If the extent of the plates were incomparably greater than their thickneſs, we may infer from n° 92, &c. that the redundant fluid and matter would be diſpoſed in parallel ſtrata, and that the actions would be the ſame at all diſtances. But ſince this is not the caſe, the diſpoſition of the fluid will be ſomewhat different; and whatever it is, the action of any ſtratum will be diminiſhed by an increaſe of diſtance. The following deſcription cannot be very different from the truth:

188 Explanation of the *primitive ſtate.*

I. The cake grows negative by cooling; and if it were alone, it would have a negative ſuperficial ſtratum on both ſides, of greater thickneſs near the edges; and the fluid would probably grow denſer by degrees to the middle, where it would have its natural denſity. This dipoſition may be inferred from n° 92, 93, and 98. But it cools in conjunction with the ſole, and the attraction of the redundant matter in the cake for the moveable fluid in the ſole diſturbs its uniform diffuſion in the ſole, and cauſes it to approach the cake. And becauſe this, in all probability, happens while the cake is ſtill a conductor, the diſpoſition of its fluid will be different fluxionary calculus in its refined form. In the preſent queſtion five acting ſtrata are to be conſidered, which renders the formulæ very complicated, and indeed intractable, unleſs we make the plates extremely thin; which, fortunately, is the beſt form of the inſtrument. We have completed this mathematical analyſis; and the popular view here given is the reſult of that computation.

199 *Condenſator* of electricity.

The electricians are no leſs obliged to Mr Volta for another machine, or inſtrument, from which the ſtudy of Nature's operations has derived, or may derive, immenſe advantages. We mean the CONDENSER, or COLLECTOR of electricity. We refer to the article ELECTRICITY in the *Encyclopædia* for a deſcription of the inſtrument, and ſome account of its effects and properties. The general effect is to render ſenſible an accumulation or deficiency of electric fluid ſo ſlight that it will not affect the moſt delicate electrometer; and it produces (at leaſt in the opinion of Mr Volta) this effect, by employing for the ſole of an electrophorus a body which is an imperfect conductor, ſuch as a plate of well dried marble, or well dried, but not baked, wood; or even a conducting body, covered with a bit of dry taffety or other ſilk. Mr Volta, Cavallo, and others, who have written a great deal on the ſubject, have attempted to ſhew how theſe ſubſtances are preferable (and they certainly are preferable in a high degree) to more perfect inſulators: but not having taken pains to form preciſe notions of the diſpoſition and action of the electric fluid in the ſituations afforded by the inſtrument, their reaſonings have not been very clear. We think that an adequate conception of the eſſentials of the propoſed inſtrument may be acquired by means of the following conſiderations:

200 Furniſh the cover of an electrophorus with a graduated electrometer, which indicates the proportional *degrees of electricity*; electrify it poſitively to any degree, ſuppoſe ſix, while held in the hand, at ſome diſtance, right over a metal plate lying on a wine glaſs as an inſulating ſtand, but communicating with the ground by a wire. Bring it gradually down toward the plate. Theory teaches, and we know it by experiment, that the electrometer will gradually ſubſide, and perhaps will reach to 2° before the electricity is communicated in a ſpark. Stop it before this happens. In this ſtate the attraction of the lying plate produces a compenſation of four degrees of the mutual repulſion of the parts of the cover, by conſtipating the fluid on its under ſurface, and forming a deficient ſtratum above. This needs no farther explanation after what has been ſaid on the charging of coated glaſs plates. Now we can ſuppoſe that the eſcape of the fluid from this body into the air begins as ſoon as electrified to the degree 6, and that it will fly to the lying plate with the degree 2, if brought nearer. If we can prevent this communication to the lying plate, by interpoſing an electric, we may electrify the cover again, while ſo near the metal plate, to the degree 6, before it will ſtream off into the air. If it be now removed from the lying plate, the fluid would raiſe the electrometer to 10, did it not immediately ſtream off; and an electric excitement of any kind which could only raiſe this body to the degree 6 by its intenſity, will, by this apparatus, raiſe it to the degree 10, if only copious enough in extent. If we do the ſame thing when the wire is taken away which connects the lying plate with the ground, we know that the ſame diminution of the electricity of the other plate cannot be produced by bringing it down into the neighbourhood of the lying plate (ſee n° 134, &c. 151, &c.).

Theory thereof.

Here we ſee the whole theory of Mr Volta's condenſer. He ſeems to have obſcured his conceptions of it by having his thoughts running upon the electrophorus lately invented by him, and is led into fruitleſs attempts to explain the advantages of the imperfect conductor above the perfect inſulator. But the apparatus is altogether different from an electrophorus, and is more analogous in its operations to a coated plate not charged nor inſulated on the oppoſite ſide; and ſuch a coated plate lying on a table is a complete condenſer, if the upper coating be of the ſame ſize with the plate of the condenſer. All the directions given by Mr Volta for the preparation of the imperfect conductors ſhew, that the effect produced is to make them as perfect conductors as poſſible for any degree of electricity that exceeds a certain ſmall intenſity, but ſuch as ſhall not ſuffer this very weak electricity to clear the firſt ſtep of the conduit. The marble muſt be thoroughly dried, and even heated in an oven, and either uſed in this warm ſtate, or varniſhed, ſo as to prevent the reabſorption of moiſture. We know that marble of ſlender dimenſions, ſo as to be completely dried throughout, will not conduct till it has again become moiſt. A thick piece of marble is rendered ſo, ſuperficially only, and ſtill conducts internally. It is then in the beſt poſſible ſtate. The ſame may be ſaid of dry unbaked wood. Varniſhing the upper ſurface of a piece of marble or wood is equivalent to laying a thin glaſs plate on it. Now this method, or covering the top of the marble, or of a book, or even the table, with a piece of clean dry ſilk, makes them all the moſt perfect condenſators. This juſt view of the matter has great advantages. It takes away the myſterious indiſtinctneſs and obſcurity which kept the inſtrument a quackiſh tool, incapable of improvement. We can now make one incomparably better and more ſimple than any propoſed by the very ingenious inventor. We need only the ſimple moveable plate. Let this be varniſhed on the under ſide with a moderately thick coat of the pureſt and hardeſt *vernis de Martin*, or coach-painters varniſh; and we have a complete condenſator by laying this on a table. If it be connected by a wire with the ſubſtance in which the weak and imperceptible electricity is excited, it will be raiſed (provided there be enough of it of that ſmall intenſity) in the proportion of the thickneſs of the varniſh to the fourth part of the diameter of the plate. This degree of condenſation will be procured by detaching the connecting wire from the inſulating handle of the condenſer, and then raiſing the condenſer from the table. It will then give ſparks, though the original electricity could not ſenſibly affect a flaxen fibre.

It muſt be particularly noted, that it can produce this condenſation only when there is fluid to condenſe; that is, only when the weak electricity is diffuſed over a greater ſpace than the plate of the condenſer. In this way it is a moſt excellent collector of the weak atmoſpheric electricity, and of all diffuſed electricity. But to derive the ſame advantage from it *in many very intereſting caſes*, ſuch as the inquiry into the electricity excited in many operations of Nature on ſmall quantities of matter, we muſt have condenſers of various ſizes, ſome not larger than a ſilver penny. To conſtruct theſe in perfection, we muſt uſe the pureſt and hardeſt varniſh, of a kind not apt to crack, and highly coercive. This requires experiment to diſcover it. Spirit varniſhes are the moſt coercive; but by their difference of contraction by cold from that of metals, they ſoon appear froſty, and when viewed through a lens, they appear all ſhivered: They are then uſeleſs. Oil varniſhes have the requiſite toughneſs, but are much inferior in coercion. We have found amber varniſh inferior to copal varniſh in this reſpect, contrary to our expectation. On the whole, we ſhould prefer the fineſt coach-painters varniſh, new from the ſhop, into which a pencil has never been dipped: and we muſt be particularly careful to clear our pencils of moiſture and all conducting matter, which never fails to taint the varniſh. We ſcarcely need remark, that the coat of varniſh on theſe ſmall condenſers ſhould be very thin, otherwiſe we loſe all the advantage of their ſmallneſs.

201 Cavallo's improvement thereof.

Mr Cavallo has ingeniouſly improved Volta's condenſer by connecting the moveable plate, after removal, with a ſmaller condenſer. The effect of this is evident from nº 130. But the ſame thing would have been generally obtained by uſing the ſmall condenſer at firſt, or by uſing a ſtill thinner coat of varniſh.

202 It will readily occur to the reader, that this inſtrument is not inſtantaneous in its operation, and that the application muſt be continued for ſome time, in order to collect the minute electricity which may be excited in the operations of nature. He will alſo be careful that the experiment be ſo conducted that no uſeleſs accumulation is made anywhere elſe. When we expect electricity from any chemical mixture, it never ſhould be made in a glaſs veſſel, for this will take a charge, and thus may abſorb the whole excited electricity, accumulating it in a neutral or inſenſible ſtate. Let the mixture be made in veſſels of a conducting ſubſtance, inſulated with as little contact as poſſible with the inſulating ſupport; for here will alſo be ſomething like a charge. Suſpend it by ſilk threads, or let it reſt on the tops of three glaſs rods, &c.

203 Bennet's *doubler* of electricity.

After this account of the Leyden phial, electrophorus, and condenſer, it is ſurely unneceſſary to employ any time in explaining Mr Bennet's moſt ingenious and uſeful inſtrument called the *doubler of electricity*. The explanation offers itſelf ſpontaneouſly to any perſon who underſtands what has been ſaid already. Mr Cavallo has with induſtry ſearched out all its imperfections, and has done ſomething to remove them, by ſeveral very ingenious conſtructions, minutely deſcribed in his Treatiſe on Electricity. Mr Bennet's original inſtrument may be freed, we imagine, as far as ſeems poſſible, by uſing a plate of air as the intermedium between the three plates of the doubler. Stick on one of the plates three very ſmall ſpherules made from a capillary tube of glaſs, or from a thread of ſealing-wax. The other plate being laid on them, reſts on mere points, and can ſcarcely receive any friction which will diſturb the experiment. Mr Nicholſon's beautiful mechaniſm for expediting the multiplication has the inconveniency of bringing the plates towards each other edgewiſe, which will bring on a ſpark or communication ſooner than may be deſired: but this is no inconvenience whatever in any philoſophical reſearch; becauſe, before this happens, the electricity has become very diſtinguiſhable as to its kind, and the degree of multiplication is little more than an amuſement. The ſpark may even ſerve to give an indication of the original intenſity, by means of the number of turns neceſſary for producing it. If the fine wires, which form the alternate connections in ſo ingenious a manner, could be tipped with little balls to prevent the diſſipation, it would be a great improvement indeed. An alternate motion, like that of a pump-handle, might be adopted with advantage. This would allow the plates to approach each other face to face, and admit a greater multiplication, if thought neceſſary.

204 Diſſipation of electricity from ſharp points.

One of the moſt remarkable facts in electricity is the rapid diſſipation by ſharp points, and the impoſſibility of making any conſiderable accumulation in a body which has any ſuch, projecting beyond other parts of its ſurface. The diſſipation is attended with many remarkable circumſtances, which have greatly the appearance of the actual eſcape of ſome material ſubſtance. A ſtream of wind blows from ſuch a point, and quickly electrifies the air of a room to ſuch a degree, that an electrometer in the fartheſt corner of the room is affected by it. This diſſipation in a dark place is, in many inſtances, accompanied by a bright train of light diverging from the point like a firework. Dr Franklin therefore was very anxious to reconcile this appearance with his theory of plus and minus electricity, but does not expreſs himſelf well ſatisfied with any explanation which had occurred to him. From the beginning, he ſaw that he could not conſider the ſtream of wind as a proof of the eſcape of the electric fluid, becauſe the ſame ſtream is obſerved to iſſue from a ſharp negative point; which, according to his theory, is not diſperſing, but abſorbing it. Mr Cavendiſh has, in our opinion, given the firſt ſatisfactory account of this phenomenon.

205 To ſee this in its full force, the phenomenon itſelf muſt be carefully obſerved. The ſtream of wind is plainly produced by the eſcape of ſomething from the point itſelf, which hurries the air along with it; and this draws along with it a great deal of the ſurrounding air, eſpecially from behind, in the ſame manner as the very ſlender thread of air from a blow-pipe hurries along with it the ſurrounding air and flame from a conſiderable ſurface on all ſides. It is in this manner that it gathers the whole of a large flame into one maſs, and, at laſt, into a very point. If the ſmoke of a little roſin thrown on a bit of live coal be made to riſe quietly round a point projecting from an electrified body, continually ſupplied from an electrical machine, the vortices of this ſmoke may be obſerved to curl in from all ſides, along the wire, forming a current of which the wire is the axis, and it goes off completely by the point. But if the wire be made to paſs through a cork fixed in the bottom of a wide glaſs tube, and if its point project not beyond the mouth of the tube, the afflux of the air from behind is prevented, and we have no ſtream; but if the cork be removed, and the wire ſtill occupy the axis of the tube, but without touching the ſides, we have the ſtream very diſtinctly; and ſmoke which riſes round the far end of the tube is drawn into it, and goes off at the point of the wire. Now it is of importance to obſerve, that whatever prevents the formation of this ſtream of wind prevents the diſſipation of electricity (for we ſhall not ſay eſcape

of electric fluid) from the point. If the point project a quarter of an inch beyond the tube, or if the tube be open behind, the ſtream is ſtrong, and the diſſipation ſo rapid, that even a very good machine is not able to raiſe a Henly's electrometer, ſtanding on the conductor, a very few degrees. If the tube be ſlipped forward, ſo that the point is juſt even with its mouth, the diſſipation of electricity is next to nothing, and does not exceed what might be produced by ſuch air as can be collected by a ſuperficial point. If the tube be made to advance half an inch beyond the point which it ſurrounds, the diſſipation becomes inſenſible. All theſe facts put it beyond a doubt that the air is the cauſe, or, at leaſt, the occaſion of the diſſipation, and carries the electricity off with it, in this manner rendering electrical the whole air of a room. The problem is reduced to explain how the air contiguous to a ſharp electrified point is electrified and thrown off.

Theory of it.

It was demonſtrated in nº 130, that two ſpheres, connected by an infinitely extended, but ſlender conducting canal, are in electrical equilibrium, if their ſurfaces contain fluid in the proportion of their diameters. In this caſe, the ſuperficial denſity of the fluid and its tendency to eſcape are inverſely as the diameters (nº 130). Now if, in imagination, we gradually diminiſh the diameter of one of the ſpheres, the tendency to eſcape will increaſe in a greater proportion than any that we can name. We know, that when the prime conductor of a powerful table-machine has a wire of a few inches in length projecting from its end, and terminating in a ball of half an inch in diameter, we cannot electrify it beyond a certain degree; for when arrived at this degree, the electricity flies off in ſucceſſive burſts from this ball. Being much more overcharged than any other part of the body, the air ſurrounding the ball becomes more overcharged by communication, and is repelled, and its place ſupplied by other air, not ſo much overcharged, which ſurrounded the other parts of the body, and is preſſed forwards into this ſpace by the general repulſion of the conductor and the confining preſſure of the atmoſphere; otherwiſe, being alſo overcharged, it would have no tendency to come to this place. Half a turn of the cylinder is ſufficient to accumulate to a degree ſufficient for producing one of theſe exploſions, and we have two of them for every turn of the cylinder. A point may be compared to an incomparably ſmaller ball. The conſtipation of the fluid, and its tendency to eſcape, muſt be greater in the ſame unmeaſurable proportion. This denſity and mutual repulſion cannot be diminiſhed, and muſt even be increaſed, by the matter of the wire forming a cone, of which the point is the apex; therefore, if there were no other cauſe, we muſt ſee that it is almoſt impoſſible to confine a collection of particles, mutually repelling, and conſtipated, as theſe are in a fine point.

206
Electricity unites chemically with air.

But the chief cauſe ſeems to be a certain chemical union which takes place between the electric fluid and a correſponding ingredient of the air. In this ſtate of conſtipation, almoſt completely ſurrounded by the air, the little maſs of fluid muſt attract and be attracted with very great force, and more readily overcome the force which keeps the electrified fluid attached to the laſt ſeries of particles of the wire. It unites with the air, rendering it electric in the higheſt degree of redundancy. It is therefore ſtrongly repelled by the maſs of conſtipated fluid which ſucceeds it within the point. Thus is the electrified air continually thrown off, in a ſtate of electrification, that muſt rapidly diminiſh the electricity of the conductor. Hence the uninterrupted flow, without noiſe or much light, when the point is made very fine. When the point is blunt, a little accumulation is neceſſary before it attains the degree neceſſary for even this minute exploſion; but this is ſoon done, and theſe little exploſions ſucceed each other rapidly, accompanied by a ſputtering noiſe, and trains of bright ſparks. The noiſe is undoubtedly owing to the atoms of the highly electrified fluid. Theſe are, in all probability, rarefied of a ſudden, in the act of electrification, and immediately collapſe again in the act of chemical union, which cauſes a ſonorous agitation of the air. This electrified air is thus thrown off, and its place is immediately ſupplied by air from behind, not yet electrified, and therefore ſtrongly drawn forward to the point, from which they are thrown off in their turn. This rapid expanſion and ſubſequent collapſing of the air is verified by the experiments of Mr Kinnerſly, related by Dr Franklin, and is ſeen in numberleſs experiments made with other views in later times, and not attended to. Perhaps it is produced by the great heat which accompanies, or is generated in the transference of electricity, and it is of the ſame kind with what occaſions the burſting of ſtones, ſplitting of trees, exploding of metals, &c. by electricity. The expanſion is either inconſiderable, or it is ſucceſſively produced in very ſmall portions of the ſubſtance expanded; for when metal is exploded in cloſe veſſels, or under water, there is but a minute portion of gazeous matter produced; and in the diſſipation by a very fine point, ſufficiently great to give full employment to a powerful machine, the ſtream of wind is but very faint, and nine-tenths of this has been dragged along by the really electrified thread of wind in the middle.

From a collation of all the appearances of electricity, we muſt form the ſame conception of the forces which operate round a point that is negatively electrified, not diſperſing, but drawing in electric fluid. It is more completely undercharged than any other part of a body, and attracts the fluid in the ſurrounding air, and the air in which it is retained, with incomparably greater force. It therefore deprives the contiguous air of its fluid, and then repels it, and then produces a ſtream like the overcharged point.

207

If a conducting body be brought near to any part of an overcharged body, the fronting part of the firſt is rendered undercharged; and this increaſes the charge of the oppoſite part of the overcharged body. It becomes more overcharged in that part, and ſooner attains that degree of conſtipation that enables the fluid to quit the ſuperficial ſeries of particles, and to electrify ſtrongly the contiguous air. The exploſion is therefore made in this part in preference to any other; and the air thus exploded is ſtrongly attracted by the fronting part of the other body, and muſt fly thither in preference to any other point. If, moreover, the fronting part of A be prominent or pointed, this effect will be produced in a ſuperior degree; and the current of electrified air, which will begin very early, will increaſe this diſpoſition to transference in this way by rarefying the air; a change which the whole courſe of electric phenomena ſhews to be highly favourable to this transference, ſerence, although we cannot perhaps form any very adequate notion how it contributes to this effect. This ſeems to be the reaſon why a great exploſion and ſnap, with a copious transference of electricity, is generally preceded by a hiſſing noiſe like the ruſhing of wind, which ſwells to a maximum in the loud ſnap itſelf.

208 If two prominences, preciſely ſimilar, and electrified in the contrary way to the ſame degree, are preſented to each other, we cannot ſay from which the current ſhould take its commencement, or whether it ſhould not equally begin from both, and a general diſperſion of air laterally be the effect; but ſuch a ſituation is barely poſſible, and muſt be infinitely rare. The current will begin from the ſide which has ſome ſuperiority of propelling force. We are diſpoſed to think that this current of material electrified ſubſtance muſt ſuffer great change during its paſſage, by mixing with the current in an oppoſite electrical ſtate coming from the other body. Any little maſs of the one current muſt ſtrongly attract a contiguous maſs of the other, and certain changes ſhould ſurely ariſe from this mixture. Theſe may, in their turn, make a great change in the *mechanical* motions of the air; and, inſtead of producing a *quaqua verſum* diſperſion of air from between the bodies, as ſhould reſult from the meeting of oppoſite ſtreams, it may even produce a collapſing of the air by the mutual ſtrong attractions of the little maſſes. Many valuable experiments offer themſelves to the curious inquirer. Two little balls may be thus preſented to each other, and a ſmoke may be made with roſin to occupy the interval between them. Motions may be obſerved which have certain analogies that would afford uſeful information to the mechanical inquirer. There muſt be ſomething of this mixture of currents in all ſuch transferences, and the moſt minute differences in the condition of a little parcel of the air may greatly affect the future motions. The moſt promiſing form of ſuch experiment would be to uſe two points of the ſame ſubſtance, ſhape, and ſize, and electrified to the ſame degree in oppoſite ſenſes.

209 Characteriſtic differences of poſitive and negative electricity.

After all care has been taken to inſure ſimilarity, there remains one eſſential difference, that *the one current is redundant in electric fluid, and the other deficient.* This circumſtance *muſt* produce characteriſtic differences of appearance. And are there not ſuch differences? Is not the pencil and the ſtar of light a characteriſtic difference? And does not this well-ſupported fact greatly corroborate the opinion of Dr Franklin, that the electric phenomena reſult from the redundancy and deficiency of *one* ſubſtance, and not from two diſtinct ſubſtances operating in a ſimilar manner? For the diſtinction in appearance is a mechanical diſtinction. Motion, direction, velocity, are perceivable in it. Locomotive forces are concerned in it; but they are ſo implicated with forces which probably reſemble chemical affinities, hardly operating beyond contact, that to extricate their effects from the complicated phenomenon ſeems a deſperate problem. There is ſome hitherto inexplicable chemical compoſition and decompoſition taking place in the transference of electricity. Of this a numerous train of obſervations made ſince the dawn of the pneumatic chemiſtry leaves us no room to doubt. The emerſion or production of light and heat is a remarkable ſign and proof. Now *this takes place along the whole path of transference;* therefore the proceſs is by no means completed at the point from which the active cauſe proceeds; and although there be certain appearances that are pretty regular, they are ſtill mixed with others of the moſt capricious anomaly. The zigzag form of the moſt condenſed ſpark, totally unlike, by its ſharp angles, to any motions producible by accelerating forces, which motions are without exception, curvilineal, makes us doubt exceedingly whether the luminous lines which we obſerve are ſucceſſive appearances of the ſame matter in different places, or whether they be not rather ſimultaneous, or nearly ſimultaneous, coruſcations of different parcels of matter in different places, indicating chemical compoſitions taking place almoſt at once; and this becomes more probable, when we reflect on what has been ſaid already of the jumbling of oppoſite currents; ſuch mixtures ſhould be expected. We have ſeen a darted flaſh of lightning which reached (in a direction nearly parallel to the horizon) above three miles from right to left; and it ſeemed to us *to be co-exiſtent;* we could not ſay at which end it began. The thunder began with a loud crack, and continued with a moſt irregular rumbling noiſe about 15 ſeconds, and ſeemed equal on both hands. We imagine that it was really a ſimultaneous ſnap, in the whole extent of the ſpark, but of different ſtrength in different places; different portions of the ſonorous agitation were propagated to the ear in ſucceſſion by the ſonorous undulations of air, cauſing it to ſeem a lengthened ſound. Such would be the appearance to a perſon ſtanding at one end of a long line of ſoldiers who diſcharge their firelocks at one inſtant. It will ſeem a running fire, of different ſtrength in different parts of the line, if the muſkets have been unequally loaded. It is inconceivable that this long zigzag ſpark can mark the track of an individual maſs of electrified air. The velocity and momentum would be enormous, and would ſweep off every thing in its way, and its path could not be angular. The ſame muſt be aſſerted of the ſtreams of light in our experiments. The velocity is ſo unmeaſurable that we cannot tell its direction. There may be very little local motion, juſt as in the propagation of ſound, or of a wave on the ſurface of water. That particular change of mutual ſituation among the adjoining atoms which occaſions chemical ſolution or precipitation may be produced in an inſtant, over a great extent, as we know that a parcel of iron filings, lying at random on the ſurface of quickſilver, will, in one inſtant, be arranged in a certain manner by the mere neighbourhood of a magnet. Is not this like the ſimultaneous precipitation of water along the whole path of a diſcharge?

But ſtill there muſt be ſome cauſe which gives theſe ſimultaneous coruſcations a ſituation with reſpect to each other, that has a certain regularity. Now the luminous *trains* (for they are not uniform *lines* of light) of almoſt continuous ſparks which are arranged between a poſitive and a negative point, ſeem to us to indicate emanation from the poſitive, and reception by the negative point. The general line has a conſiderable reſemblance to the path of a body projected from the poſitive point, repelled by it, and attracted by the negative point. This will appear to the mechanician on a very little reflection. If the curve were completely viſible, it would ſomewhat reſemble thoſe drawn between P and N in fig. 35. PABN overpaſſes the point N, and comes to it from behind ; P *a b* N lies within the other, and arrives in a direction nearly perpendicular to the axis ; P *α* BN deſcribes a ſtraight line, and arrives in the direction PN. As the chemical compoſition advances, the light is diſengaged or produced, and therefore the appearances are more rare as we advance farther in the direction in which they are produced ; and there would perhaps be no appearance at all at the point where the motion ends, were it not that the few remaining parcels, where the compoſitions or decompoſitions have not been completed, are crowded together at the negative point, *incomparably* more than in any other part of the track. We think that theſe conſiderations offer ſome explanation of the appearance of the pencil and ſtar, which are ſo uniformly characteriſtic of the poſitive and negative electricities : but we ſee many grounds of uncertainty and doubt, and offer it with due diffidence.

210 Lichtenberg's electricwriting affords diſtinctive marks of + and —.

The curious figures obſerved by Mr Lichtenberg, formed by the duſt which ſettles on a line drawn on the face of a mirror by the poſitive and by the negative knobs of a charged jar, are alſo uniformly characteriſtic of the two electricities. Theſe are mechanical diſtinctions, indicating certain differences of accelerating forces. We muſt refer the curious reader to Lichtenberg's Diſſertations in the *Gottengen Commentaries ;* to the *Publication of the Haerlem Society ;* to the *Gotha Magazine* ; to *Diſſertations by Spath* at Altdorff, and other German writers.

211 Diſſipation of electricity into the air is proportional to the denſity.

It only remains for us to take notice of the general laws of the diſſipation of electricity into the air, and along imperfect inſulators. On this ſubject we have ſome valuable experiments of Mr Coulomb, publiſhed in the Memoirs of the Academy of Sciences of Paris for 1785.

Theſe experiments were made with the aſſiſtance of an electrometer of a particular conſtruction, which ſhall be deſcribed under the article ELECTROMETER.

The general reſult of Mr Coulomb's experiments was, that the momentary diſſipation of moderate degrees of electricity is proportional to the degree of electricity at the moment. He found that the diſſipation is not ſenſibly affected by the ſtate of the barometer or thermometer ; nor is there any ſenſible difference in bodies of different ſizes or different ſubſtances, or even different figures, provided that the electricity is very weak.

212 But he found the diſſipation greatly affected by the different ſtates of humidity of the air. Sauſſure's hygrometer has its ſcale diſtinctly related to the quantity of water diſſolved in a cubic foot of the air. The following little table ſhews an evident relation to this in the diſſipation of electricity :

Hygrometer.	Grains water in cubic foot.	Diſſipation per minute.
69	6,197	$\frac{1}{60}$
75	7,295	$\frac{1}{41}$
80	8,045	$\frac{1}{20}$
87	9,221	$\frac{1}{14}$

Hence it follows, that the diſſipation is very nearly in the triplicate ratio of the moiſture of the air. Thus if

$\frac{60}{41}$ be conſidered as $= \left.\overline{\frac{7{,}197}{6{,}180}}\right|^{m}$ we have $m = 2{,}764$.

$\frac{60}{29}$ . . $= \left.\overline{\frac{8{,}045}{6{,}180}}\right|^{m}$ gives $m = 2{,}76$.

$\frac{60}{14}$ - - $= \left.\overline{\frac{9{,}220}{6{,}180}}\right|^{m}$ gives $m = 3{,}61$

Hence, at a medium, $m = 3{,}40$.

We ſhould have obſerved, that the ingenious author took care to ſeparate this diſſipation by immediate contact with the air, from what was occaſioned by the imperfect inſulation afforded by the ſupports.

213 Diminution of repulſion is double of the diſſipation.

It muſt alſo be remarked here, that the immediate object of obſervation in the experiments is the diminution of repulſion. This is found to be, in any given ſtate of the air, a certain proportion of the whole repulſion at the moment of diminution : but this is double of the proportion of the denſity of the electric fluid ; for it muſt be recollected, that the repulſions by which we judge of the diſſipation are mutual, exerted by every particle of fluid in the ball *t* of Coulomb's electrometer, on every particle in the ball *a*. It is therefore proportional to the electric denſity of each ; and therefore, during the whole diſſipation, the denſities retain their primitive proportion ; therefore, the diminution of the repulſion being as the diminution of the products of the denſities, it is as the diminution of the ſquares of either. If therefore the denſity be repreſented by d, the mutual repulſion is repreſentable by d^2, and its momentary diminution by the fluxion of d^2 ; that is, by $2 d \dot{d}$, or $2\dot{d} \times d$. Now $2 \dot{d} \times d$ is to d^2 as $2 d$ is to d ; and therefore the diminution of repulſion obſerved in our experiment bears to the whole repulſion twice as great a proportion as the diminution of denſity, or the quantity of fluid diſſipated, bears to the whole quantity at the moment. For example, if we obſerve the repulſion diminiſhed $\frac{1}{40}$, we conclude that $\frac{1}{80}$ of the fluid has eſcaped.

214 Mr Coulomb has not examined the proportion between the diſſipations from bodies of different ſizes. A great and a ſmall ſphere, communicating by a very long canal, have ſuperficial denſities, and tendencies to eſcape, inverſely proportional to the diameters. A body of twice the diameter has four times the ſurface ; and though the tendency to eſcape be twice as ſmall, the ſurface is four times as great. Perhaps the greater ſurface may compenſate for the ſmaller denſity, and the quantity of fluid actually gone off may be greater in a large ſphere. This may be made the ſubject of trial.

215 Diſſipation depends on the ſtate of the air.

It muſt be kept in mind, that the law of diſſipation aſcertained by theſe experiments, relates to one given ſtate of the air, and that it does not follow that in another ſtate, containing perhaps the ſame quantity of water, the diſſipation ſhall be the ſame. The air is ſuch a heterogeneous and variable compound, that it may have very different affinities with the electric fluid. Mr Coulomb thought that he ſhould infer from his numerous experiments, that the diſſipation did not increaſe in the ratio of the cube of the water diſſolved in the air, unleſs it was nearly as much as it could diſſolve in that temperature. This indeed is conformable to general obſervation : for air is thought dry when it dries quickly any thing expoſed to it ; that is, when not nearly ſaturated with moiſture. Now it is well known, that what is thought dry air, is favourable to electricity.

216 Diſſipation by imperfect inſulators.

The diſſipation along imperfect inſulators is brought about in a way ſomewhat different from the manner of its eſcaping by electrifying the contiguous air and going off with it. It ſeems to be chiefly, if not ſolely, along the ſurface of the inſulating ſupport that the electricity is diffuſed, and that the diffuſion is produced there chiefly by the moiſture which adheres to it. It is not very eaſy to form a clear notion of the manner, but Mr Coulomb's explanation ſeems as ſatisfactory as any we have ſeen.

Procedure thereof.

Water adheres to all bodies, ſticking to their ſurfaces. This adheſion prevents it from going off when electrified; and it is therefore ſuſceptible of a higher degree of electrification. If we ſuppoſe that the particles of moiſture are uniformly diſpoſed along the ſurface, leaving ſpaces between them, the electricity communicated to one particle muſt attain a certain denſity before it can fly acroſs the inſulating interval to the next. Therefore, when ſuch an imperfect conductor is electrified at one end, the electricity, in paſſing to the other, will be weakened at every ſtep. If we take three adjacent particles *a*, *b*, *c*, of this conducting matter, we learn, from n° 105, that the motion of *b* is ſenſibly affected only by the difference of *a* and *c*; and therefore that the paſſage of electricity from *b* to *c* requires that this difference be ſuperior or equal to the force neceſſary for clearing this coercive interval. Let a particle paſs over. The electric denſity of the particle *b* of conducting matter is diminiſhed, while the denſity of the particle on the other ſide of *a* remains as before. Therefore ſome will paſs from *a* to *b*, and from the particle preceding *a* to *a*; and ſo on, till we come to the electrified end of this imperfect inſulator. It is plain from this conſideration, that we muſt arrive at laſt at a particle beyond *c*, where the whole repulſion of the preceding particle is juſt ſufficient to clear this interval. Some will come over, whoſe repulſion, now acting in the oppoſite direction, will hinder any fluid from ſupplying its place in the particle which it has quitted. Here the transference will ſtop, and beyond this the inſulation is complete. There is therefore a mathematical relation between the inſulating power, and the length of the canal, which may be aſcertained by our theory; and thus another opportunity obtained for comparing it with obſervation. That this inveſtigation may be as ſimple as poſſible, we may take a very probable caſe, namely, where the inſulating, or, to name it more graphically, the coercive interval is equal in every part of the canal.

217 Theory thereof.

Let R be the coercive power of the inſulator; that is, let R be the force neceſſary for clearing the coercive interval. Let a ball C (fig. 36) be ſuſpended by a ſilk thread AB, and let C repreſent the quantity of its redundant fluid; and let the denſity in the different points of the canal be as the ordinates AD, P *d*, &c. of ſome curve line D *d* B, which cuts the axis in B where the thread begins to inſulate completely. Let P *p* be an element of the axis. Draw the ordinate *p f*, the tangent *d f* F, and the normal *d* E, and *f e* perpendicular to P *d*. Let AC be $= r$, AP $= x$, P $d = y$. Then P $p = \dot{x}$, and $d\,e = -\dot{y}$. We have ſeen, that the only ſenſible action on the particle of fluid in P is $-\frac{y\dot{y}}{\dot{x}}$ (ſee n° 105), when the action of the redundant fluid in the globe on the particle P having the denſity *y*, is repreſented by $\frac{\mathrm{C}\,y}{(r+x)^2}$. Therefore we have $\frac{y\dot{y}}{\dot{x}} =$ R, the coercive power of the thread. This is ſuppoſed to be conſtant. Therefore $\frac{\mathrm{P}\,d \times d\,e}{\mathrm{P}\,p}$ is equal to ſome conſtant line R. But P *p*, or $f\,e : d\,e = \mathrm{P}\,d :$ PE. Therefore the ſubnormal PE is a conſtant line. But this is the property of the parabola alone; and the curve of denſity D *d* B is a parabola, of which the parameter is 2 PE, or 2 R.

218 Variation of denſity in the inſulator.

Cor. 1. The denſities in different points of an imperfect inſulator, are as the ſquare roots of their diſtance from the point of complete inſulation: For $\mathrm{P}\,d^2 : \mathrm{AD}^2 = \mathrm{BP} : \mathrm{BA}$.

219 Length neceſſary for inſulation ÷ denſity²

2. The length of canal required for inſulating different denſities of electricity are as the ſquares of the denſities. For $\mathrm{AB} = \frac{\mathrm{AD}^2}{2\,\mathrm{PE}}$; and PE has been ſhewn to be a conſtant quantity. Indeed we ſee in the demonſtration, that BP would inſulate a ball, whoſe electric denſity is P *d*, and $\mathrm{BA} : \mathrm{BP} = \mathrm{AD}^2 : \mathrm{P}\,d^2$.

220 Alſo ÷ $\frac{1}{\text{coercion}}$.

3. The length neceſſary for inſulation is inverſely as the coercive force of the canal, and may be repreſented generally by $\frac{\mathrm{D}^2}{\mathrm{R}}$. For AB is $= \frac{\mathrm{DA}^2}{2\,\mathrm{PE}} = \frac{\mathrm{D}^2}{2\,\mathrm{R}}$

Mr Coulomb has verified theſe concluſions by a very ſatisfactory ſeries of experiments, by the aſſiſtance of his delicate electrometer, which is admirably ſuited for this trial. The ſubject is ſo intereſting to every zealous ſtudent of electricity, that Mr Canton, Dr B. Wilſon, Mr Waitz, Wilcke, and others, have made experiments for eſtabliſhing ſome meaſure of the conducting powers of different ſubſtances. It was one of the firſt things that made the writer of this article ſuppoſe that electric action was in the inverſe duplicate ratio of the diſtances: for, as early as 1763, he had found, that the lengths of capillary tubes neceſſary for inſulation were as the ſquares of the repulſions of the ball which they inſulated. The mode of reaſoning offers of itſelf, and the fluxionary expreſſion of the inſulating power, *viz.* $\frac{d\dot{d}}{\dot{x}}$ led immediately to a force proportional to $\frac{1}{x^2}$. Numerous experiments were made, which we do not give here, becauſe the public are already poſſeſſed of thoſe of Mr Coulomb.

Explanation of the efficacy of Volta's *condenſer*.

This diſcuſſion explains, in a ſatisfactory manner, the operation of the condenſer, as deſcribed by Mr Volta. The weak degrees of electricity, which are rendered ſufficiently ſenſible by the inſulation of the plate of dry marble, are completely inſulated by the perhaps thin ſtratum that has been ſufficiently dried, while the reſt conducts with an efficacy ſufficient for permitting the accumulation.

221

When we reflect on the theory now delivered, we ſee that the formulæ determine the diſtribution of the fluid along an imperfect conductor in a certain manner, on the ſuppoſition that a *certain determinate* doſe has been imparted to the ball: Becauſe this doſe, by diffuſing itſelf from particle to particle of the conducting matter, will diffuſe itſelf all the way to B, in ſuch a manner that the repulſion ſhall everywhere be in equilibrio with the *maximum* of the coercive force of the inſulating interval. But it muſt be farther noticed, that this reſiſtence is not *active*, but coercitive, and we may compare it to friction or viſcidity. Any repulſion of electric fluid, which falls ſhort of this, will not diſturb the ſtability of the fluid ſpread along the canal, according to any law whatever. So that if AD repreſent the electric denſity of the globe, and remain conſtant, any curve of denſity will anſwer, if $\frac{d\dot{d}}{\dot{x}}$ be everywhere leſs than R. It is therefore an indeterminate problem to aſſign, in general, the diſpoſition of fluid in the canal. The denſity is as the ordinates of a parabola only on the ſuppoſition that the maximum of R is everywhere the ſame. And, in this caſe, the diſtance AB is a minimum: for, in other caſes of denſity, we muſt have $\frac{d\dot{d}}{\dot{x}}$ leſs than R. If, therefore, we vary a ſingle element of the curve D d B, in order that the ſtability of the fluid may not be diſturbed, having $\dot{d}$ conſtant, we muſt neceſſarily have $\dot{x}$ larger, that $\frac{d\dot{d}}{\dot{x}}$ may ſtill be leſs than R; that is, we muſt lengthen the axis.

We ſee alſo, that to aſcertain the diſtribution in a conducting canal is a determinate problem; whereas, in imperfect conductors, it is indeterminate, but limited by the ſtate of the fluid, when it is ſo diſpoſed that in every point the action of the fluid is in equilibrio with the maximum of reſiſtance. This conſideration will be applied to a valuable purpoſe in the article MAGNETISM.

222 Explanation of a curious and important fact; and method of increaſing a charge.

This doctrine gives, in our opinion, a very ſatisfactory explanation of the curious obſervations of Mr Brookes and Mr Cuthbertſon, mentioned in n° 167. namely, that damping the inſide of a coated jar diminiſhes the riſk of exploſion, and enables it to hold a higher charge. We learn here, that there is no denſity ſo great but that the leaſt imperfect conductor will inſulate it, if long enough; and that the coercive quality of an imperfect conductor may be conceived ſo conſtituted from A towards B, that the denſities ſhall diminiſh in any ratio that we pleaſe, ſo that the variation of denſity (the cauſe of motion) may everywhere, even to the inſulating point B, be very ſmall. However great the conſtipation at the edge of the metallic coating may be, an imperfect conductor may be continued outward from that edge, and may be ſo conſtituted, that the conſtipation ſhall diminiſh by ſuch gentle gradations, that an exploſion ſhall be impoſſible. An uniform dampneſs will not do this, but it will diminiſh the abruptneſs of the variation of denſity. The ſtate of denſity beyond the edge of the coating of a charged jar, very clean and dry, may be repreſented by the parabolic arch D i a. This may be changed by damping, or properly dirtying (to uſe Mr Brookes's phraſe), to D f B; which is evidently preferable. We think it by no means difficult to contrive ſuch a continuation of imperfectly conducting coating. Thus, if gold leaf can be ground to an impalpable powder, it may be mixed with an oil varniſh in various proportions. Zones of this gold varniſh may be drawn parallel to the edge of the coating, decreaſing in metal as they recede from the edge. By ſuch contrivances it may be poſſible to increaſe the retentive power to a great degree.

223 Cautions in deducing meaſures from experiments.

This doctrine farther teaches us, that many precautions muſt be taken when we are making experiments from which meaſures are to be deduced; and it points them out to the mathematician. In particular, when bodies, ſupported by inſulators, are electrified to a high degree, the ſupports may receive a quantity of fluid, which may greatly diſturb the reſults; and this quantity, by exerting but a weak action on the parts of the canal, may continue for a very long time, and not be removed but with great difficulty. In ſuch caſes, it will be neceſſary to uſe new ſupports in every experiment. Not knowing, or not attending to this circumſtance, many erroneous opinions have been formed in ſome delicate departments of electrical reſearch.

Mr Coulomb's experiments on this ſubject are chiefly valuble for having ſtated the relation between the intenſity of the electricity, or, as he expreſſes it, the electric denſity, and the lengths of ſupport neceſſary for the complete inſulation. But, as the abſolute intenſities have all been meaſured by his electrometer, and he has not given its particular ſcale, we cannot make much uſe of them till this be done by ſome electrician.

224 Inſulating powers of various ſubſtances.

Mr Coulomb found, that a thread of gum lac was the moſt perfect of all inſulators, and is not leſs than ten times better than a ſilk thread as dry as it can be made, if we meaſure its excellence by its ſhortneſs. In a conſiderable number of experiments, he found that a thread of gum lac, of 1,5 inches long, inſulated as well as a fine ſilk thread of 15 inches. When the thread of ſilk was dipped in fine ſealing-wax, it was equal to the pure lac, if ſix inches long, or four times its length. If we meaſure their excellence by the intenſities with which they inſulate, lac is three times better than the dry thread, and twice as good as the thread dipped in ſealing-wax: ſo that a fibre of ſilk, even when included in the lac, diminiſhes its inſulating power. We alſo learn, that the diſſipation along theſe ſubſtances is not entirely owing to moiſture condenſed or adherent on their ſurfaces, but to a ſmall degree of conducting power. We have repeated many of theſe experiments, and find that the conducting power of ſilk thread depends greatly on its colour. When of a brilliant white, or if black, its conducting power ſeems to be the greateſt, and a high golden yellow, or a nut brown, ſeemed to be the beſt inſulators; doubtleſs the dyeing drug is as much concerned as the fibre.

Glaſs, even in its dryeſt ſtate, and in ſituations where moiſture could have no acceſs to it, *viz.* in veſſels containing cauſtic alkali dried by red heat, or holding freſh made quicklime, appeared in our experiments to be conſiderably better than ſilk; and where drawn into a ſlender thread, and covered with gum lac (melted), inſulated when three times the length of a thread of lac; but we found at the ſame time, that extreme fineneſs was neceſſary, and that it diſſipated in proportion to the ſquare of its diameter. It was remarkably hurt by having a bore, however fine, unleſs the bore could alſo be coated with lac. Human hair, when completely freed from every thing that water could waſh out of it, and then dried by lime, and coated with lac, was equal to ſilk. Fir, and cedar, and larch, and the roſe-tree, when ſplit into filaments, and firſt dried by lime, and afterwards baked in an oven which juſt made paper become faintly brown, ſeemed hardly inferior to gum lac.

The *white woods*, as they are called, and mahogany, were much inferior. Fir baked, and coated with melted lac, ſeems therefore the beſt ſupport when ſtrength is required. The lac may be rendered leſs brittle by a minute portion of pure turpentine, which has been cleared of water by a little boiling, without ſenſibly increaſing its conducting power. Lac, or ſealing-wax, diſſolved in ſpirits, is far inferior to its liquid ſtate by heat.

Theſe obſervations may be of uſe for the conſtruction of electrical machines of other electrics than glaſs.

General reflections

We have now given a compariſon of the hypotheſis of Mr Æpinus with the chief facts obſerved in electricity, diverſified by every circumſtance that ſeemed likely to influence the reſult, or which is of importance to be known. We truſt that the reader will agree with us in ſaying that the agreement is as complete as can be expected in a theory of this kind; and that the application not only ſeems to explain the phenomena, but is practically uſeful for directing us to the procedures which are likely to produce the effect we wiſh. Thus, ſhould our phyſiological opinions ſuggeſt that copious transference of fluid is proper, our hypotheſis points out the moſt effectual and the moſt convenient methods for producing it. We learn how to conſtipate the fluid in a quieſcent ſtate, or how to abſtract as much of it as poſſible from any part of a patient; we can do this even in the internal parts of the body. We had once an opportunity of ſeeing what we thought the cure of a paralyſis of the gullet. Electricity was tried, firſt in the way of ſparks, and then ſmall ſhocks taken acroſs the trachea. Theſe could not be tolerated by the patient. The ſurgeon wiſhed to give a ſhock to the œſophagus without affecting the trachea. We recommended a leaden piſtol bullet at the end of a ſtrong wire, the whole dipped in melted ſealing-wax. This was introduced a little way, we think not more than three inches, into the gullet, which the palſy permitted. A very ſlight charge was given to it in a few ſeconds; and the firſt ſhock produced a convulſion in the muſcle, and the ſecond removed the diſorder completely. Here the ball formed the inner, and the gullet the outer, coating of the little Leyden phial.

The theory of Æpinus is only a hypotheſis.

Notwithſtanding the flattering teſtimony given by the great conformity of this doctrine with the phenomena, we ſtill chooſe to preſent it under the title of a hypotheſis. We have never ſeen the electric fluid in a ſeparate ſtate; nor have we been able to ſay in what caſes it abounds, or when it is deficient. After what we have ſeen in the late experiments of that philanthropic philoſopher Count Rumford on the production of heat by friction, we think that we cannot be too cautious on what grounds we admit inviſible agents to perform the operations of Nature. We think that all muſt acknowledge that thoſe experiments tend very much to ſtagger our belief in the exiſtence of a fluid *ſui generis*, a fire, heat, caloric, or what we pleaſe to call it; and all will acknowledge, that no better proofs can be urged for the exiſtence of an electric fluid.

225
The reality of an electric fluid is denied.

Accordingly, many acute and ingenious perſons have rejected the notion of the exiſtence of an electric fluid, and have attempted to ſhew that the phenomena proceed, not from the preſence of a peculiar *ſubſtance*, but from peculiar *modes*; as we know that ſound, and ſome concomitant motions and other mechanical appearances, are the reſults of the elaſtic undulations of air; and as Lord Bacon and others have explained the effects of fire by elaſtic undulations of the integrant particles of tangible matter.

Requiſites for a juſt theory.

We have ſeen nothing, however, of this kind that appears to give any explanation of the motions, preſſures, and other mechanical appearances of electricity. We peremptorily require, that every doctrine which claims the name of an explanation, ſhall be perfectly conſiſtent with the acknowledged laws of mechaniſm; and that the explanation ſhall conſiſt in pointing out thoſe mechanical laws of which the facts in electricity are particular inſtances. It is no difficult matter to preſent an intricate or complex phenomenon to our view, in ſuch a form, that it ſhall have ſome reſemblance to ſome other complex phyſical fact, more familiar, perhaps, but not better underſtood. The ſpecious appearance of ſimilarity, and the more familiar acquaintance with the other phenomenon, diſpoſe us to conſider the compariſon as a ſort of explanation, or, at leaſt, an illuſtration, and to have a ſort of indolent acquieſcence in it as a theory.

But this will not do in the preſent queſtion: For we have here ſelected a particular circumſtance, the obſerved motions occaſioned by electricity, and called *attractions* and *repulſions*—a circumſtance which admits of the moſt accurate examination and compariſon with any explanation that is attempted. In ſuch a caſe, a vague picture would ſpeedily vaniſh into air, and prove to be nothing but figurative expreſſions.

226
No advantage is gained by the hypotheſis of two fluids.

Many philoſophers, and among them ſome reſpectable mathematicians, have ſupported the doctrine of Du Fay, Symmer, Cigna, &c. who employ two fluids as agents in all electrical operations. It muſt be granted that there are ſome appearances, where the explanation by means of two fluids ſeems, at firſt ſight, more palpable and eaſier conceived. But whenever we attempt to obtain *meaſures*, and to ſay what will be the preciſe kind and degree of the action, we find ourſelves obliged to aſſign to the particles of thoſe fluids actuating mechanical forces preciſely equivalent to thoſe aſſigned by Æpinus to his ſingle fluid. Then we have to add ſome myſterious unexplained connections, both with each other and with the other particles of tangible matter. If we except Mr Prevoſt, in his *Eſſai ſur les Forces Magnetiques et Electriques*, we do not recollect an author who has ventured to ſubject his ſyſtem to ſtrict examination, by pointing out to us the laws of action according to which he conceives the particles influence each other. We ſhall have a proper opportunity, in the article MAGNETISM, to give this author's theory the attention it really merits. We venture to ſay, that all the chemical theories of electricity labour under theſe inconveniences, and have acquired their influence merely from the inattention of their partiſans to the laws of mechanical motion, and require, in order to reconcile them with thoſe laws, the adoption of powers ſimilar to Æpinus's attractions and repulſions. Slight reſemblances to phenomena, which ſtand equally in need of explanation, have contented the partiſans of ſuch theories, and figurative language and metaphorical conceptions have taken place of preciſe diſcuſſion. It would be endleſs to examine them all.

227
Hypotheſis of Profeſſor Ruſſel.

The moſt ſpecious of any that we know was publicly read in the univerſity of Edinburgh by the late Mr James Ruſſel, Profeſſor of natural philoſophy; a perſon

ELECTRICITY. PLATE XXVI.

Fig. 29.

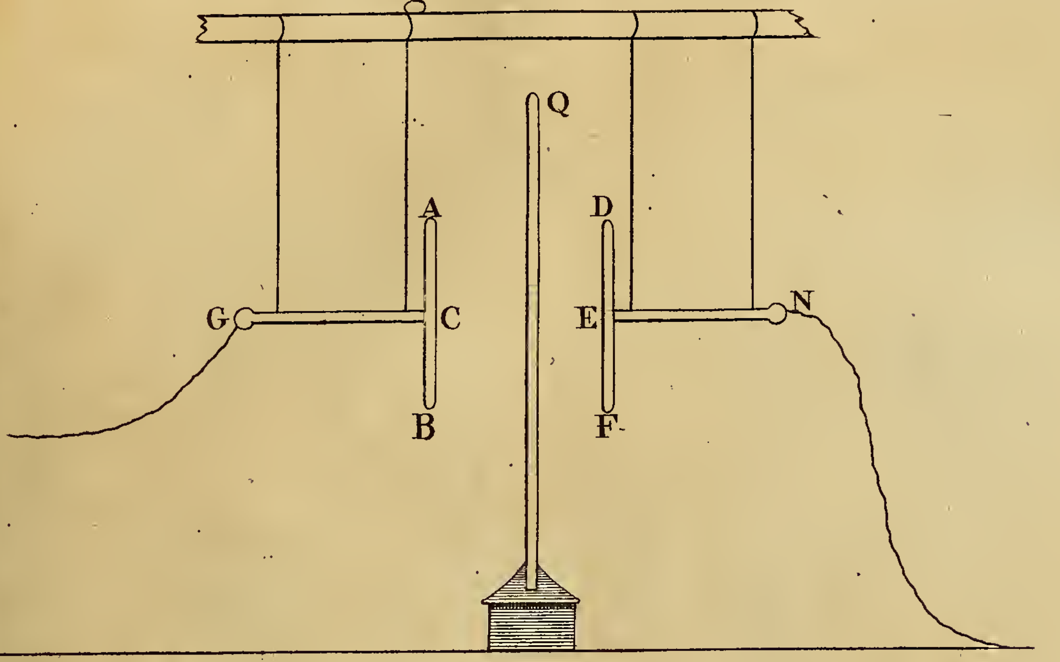


Fig. 30.

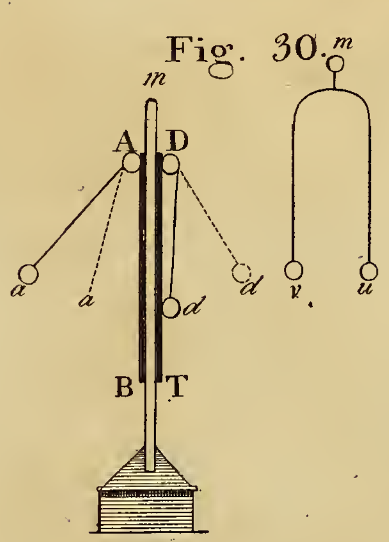


Fig. 31.

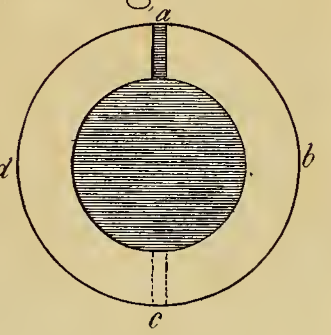


Fig. 32.

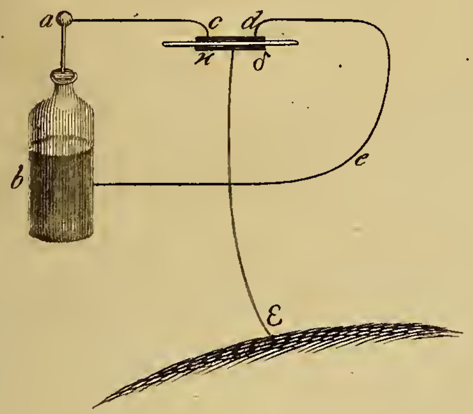


Fig. 34.

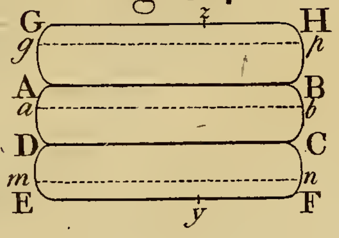


Fig. 33.

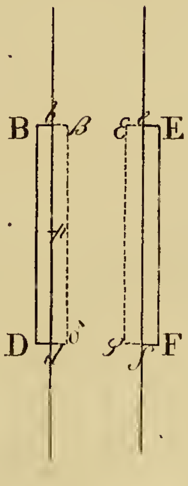


Fig. 35.

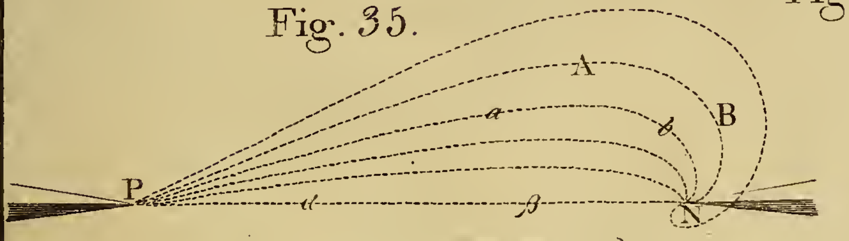


Fig. 36.

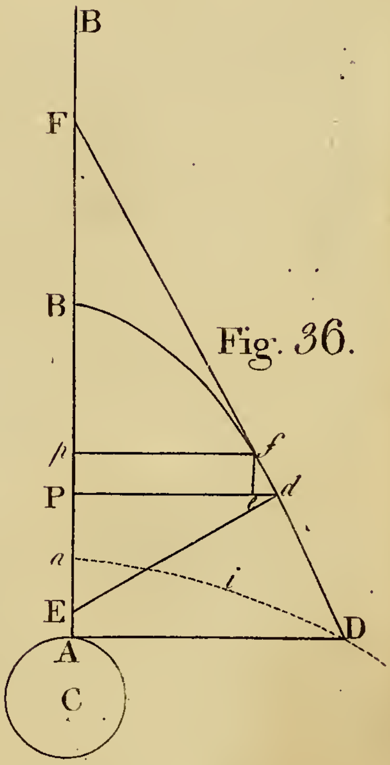


Fig. 37.

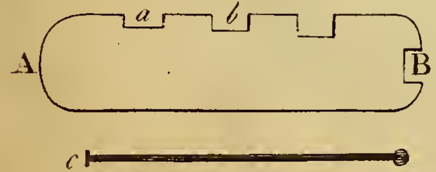
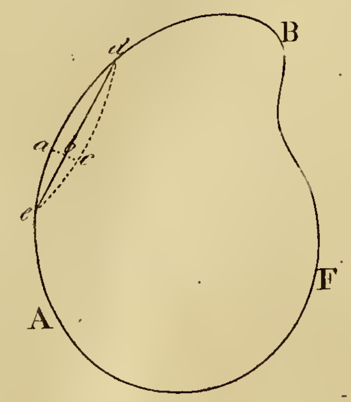


Fig. 38.



ſon of the moſt acute diſcernment, and an excellent reaſoner. It was delivered to his pupils, not as a *theory*, but as a *conjecture*, founded on Lord Kames's theory of ſpontaneous evaporation, which had obtained a very general reception; a conjecture, ſaid the Profeſſor, founded on ſuch reſemblances as made a ſimilarity of operation very probable, and was an incitement and direction to the philoſopher to a proper train of experimental diſcuſſion. We ſay this on the authority of his pupils in the years 1767, 1768, and 1769, and of ſome notes in his own hand writing now in our poſſeſſion.

Mr Ruſſel conſidered the electrical phenomena as the reſults of the action of a ſubſtance which may be called the *electrical fluid*, which is connected with bodies by attractive and repulſive forces acting at a diſtance, and diminiſhing as the diſtance increaſes.

Mr Ruſſel ſpeaks of the electric fluid as a compound of ſeveral others; and, particularly, as containing elementary fire, and deriving from it a great elaſticity, or mutual repulſion of its particles. This, however, is different from the elaſticity or mutual repulſion of the particles of air, becauſe it acts at a diſtance; whereas the particles of air act only on the adjoining particles. By this conſtitution, bodies containing more electric fluid than the ſpaces around them repel each other.

The particles of this electric fluid attract the particles of other bodies with a force which diminiſhes by diſtance.

The characteriſtic ingredient of this fluid is ELECTRICITY *properly ſo called*. This is united with the elaſtic fluid by chemical affinity, which Mr Ruſſel calls *elective attraction*, a term introduced into chemiſtry by Dr Cullen and Dr Black. This extends to all diſtances, but not preciſely by the ſame law as the mutual repulſion of the particles of the other fluid, and in general, it repreſſes the repulſions of that fluid while in this ſtate of compoſition. This *electricity*, moreover, attracts the particles of other bodies, but with certain elections. Non-electric or conducting bodies are attracted by it at all diſtances; but electrics act on it only at very ſmall and inſenſible diſtances. At ſuch diſtances its particles alſo attract each other.

By this conſtitution, the compound electric fluid repels its own particles at all conſiderable diſtances, but attracts at very ſmall diſtances. It attracts conducting bodies at all diſtances, but non-conductors, only at very ſmall diſtances. The phenomena of light and heat are conſidered as marks of partial decompoſition, and as proofs of the preſence of elementary fire in the compound: the ſmell peculiar to electricity, and the effect on the organ of taſte, are proofs of decompoſition and of the complex nature of the fluid.

Bodies (conductors) containing electric fluid, repel each other at conſiderable diſtances, but, if forced very near, attract each other. Electrics can contain it only in conſequence of the *electricity* in the compound. Part of this electricity muſt be attached to the ſurface in a non-elaſtic ſtate; becauſe when it is brought ſo near as to be attracted, its particles are within the ſpheres of each other's action, and this redoubled attraction overcomes the repulſion occaſioned by its union with the other ingredient; and the electric fluid is partly decompoſed, and the *electricity*, properly ſo called, adheres to the ſurface of the electric, *as the water of damp air adheres to a cold pane of glaſs in our windows*. Alſo, by this conſtitution, electric fluid may appear in two ſtates; elaſtic, like air, when entire; and unelaſtic, like water, when partly decompoſed by the attraction of electrics.

Electricity may be forced into this unelaſtic union by various means; by friction, which forces the electric fluid contained in the air into cloſe contact, and thus occaſions this decompoſition of the fluid and the union of its *electricity* with the ſurface. This operation is compared by Mr Ruſſel to the forcible wetting of ſome powders, ſuch as lycoperdon, which cannot be wetted without ſome difficulty and mechanical compreſſion; after which it adheres to water ſtrongly. It may be thus united in ſome natural operations, as is obſerved in the melting and freezing of ſome ſubſtances in contact with electrics; and it may be thus forced into union by means of metallic coatings, into which the electric fluid is forced by an artful employment of its mutual repulſions. This operation is compared to the condenſation of the moiſture of damp air by a cold pane of the window; and the evacuation of the other ſide of the coated pane is compared to the evaporation of the moiſture from the other ſide of the window pane, in conſequence of the heat which muſt emerge from the condenſed vapour. We find in the Profeſſor's notes abovementioned many ſuch partial analogies, employed to ſhew the ſtudents that *ſuch* things are ſeen in the operations of Nature, and that his conjecture merits attention.

The intelligent reader will ſee that the general reſults of this conſtitution of the electric fluid will tally pretty well with the ordinary electrical phenomena; and, accordingly, this *conjecture* was received with great ſatisfaction. We remember the being much pleaſed with it, as we heard it applied by Mr Ruſſel's pupils, many of whom will recollect what is here put on record. But the attentive reader will alſo ſee, that all this intricate combination of different kinds of attraction and repulſion is nothing but mere accommodations of hypothetical forces to the phenomena. How incomparably more beautiful is the ſimple hypotheſis of Æpinus, which, without any ſuch accommodations, tallies ſo preciſely with all the phenomena that have yet been obſerved? Here no diſtinction of action is neceſſary, and all the varieties are conſequences of a circumſtance perfectly agreeable to general laws; namely, that the internal ſtructure of ſome ſubſtances may be ſuch as obſtructs the motion of the electric fluid through the pores—Nothing is more likely.

228
Hypotheſis of Mr de Luc.

Several years after the death of the Scotch Profeſſor in 1773, a theory very much reſembling this acquired great authority, being propoſed to the philoſophers by the celebrated naturaliſt Mr de Luc. This gentleman having long cultivated the ſtudy of meteorology with unwearied aſſiduity and great ſucceſs, and having been ſo familiarly converſant with expanſive fluids, and the affinities of their compounds, was diſpoſed to ſee their operations in almoſt all the changes on the ſurface of this globe. Electricity was too buſy an actor in our atmoſphere to eſcape his particular notice. While the mechanical philoſophers endeavoured to explain its effects by accelerating forces attracting and repelling, Mr de Luc endeavoured to explain them by means of the expanſive properties of aeriform fluids and gaſes, and by their chemical affinities, compoſitions, and decompoſitions. He had formed to himſelf a peculiar opinion concerning the conſtitution of our atmoſphere, and had explained the condenſation of moiſture, whether of ſteam or of damp aeriform fluids, in a way much more refined than the ſimple theory of Dr Hooke, *viz.* ſolution in air. He conſiders the compound of air and fire as the *carrier* of the water held in ſolution in damp air, and the fire as the general carrier of both the air and the moiſture. Even *fire* is conſidered by him as a *vapour*, of which *light* is the *carrier*. When this damp air or ſteam is applied to a cold ſurface, ſuch as that of a glaſs pane, it is decompoſed. The water is attracted by the pane by chemical affinity, and attaches itſelf to the ſurface. The fire, thus ſet at liberty, acts on the pane in another way, producing the equilibrium of temperature, and the expanſion of the pane. Acting in the ſame manner on the moiſture which chances to adhere to the other ſide, in a proportion ſuited to its temperature, it deſtroys their union, enters into chemical combination with the moiſture, and fits it for uniting with the air on the other ſide, or carries it off. Having read Mr Volta's theory of *electric influences*, by which that philoſopher was enabled to give a ſcientific narration and arrangement of the phenomena of the *electrophorus* newly invented by himſelf, and which is called an explanation of thoſe phenomena, Mr de Luc imagined that he ſaw a cloſe analogy between thoſe *influences* on the plates of the electrophorus and the *hygroſcopic* phenomena of the condenſation and evaporation of moiſture. In ſhort, he was ſtruck with the reſemblance between the condenſation of moiſture on one ſide of a glaſs pane, and its evaporation from the other; and the accumulation of electric fluid on one ſide of a coated pane, and the abſtraction of it from the other. Subſequent examination pointed out to him the ſame analogy between all other *hygroſcopic* and *electric* phenomena.

He therefore immediately formed a ſimilar opinion concerning the electric operations. It may be expreſſed briefly as follows:

229 The electrical phenomena are the operations of an expanſive ſubſtance, called the *electric fluid*. This conſiſts of two parts: 1. *Electric matter*, which is the gravitating part of the compound; and *electric deferent fluid*, or *carrying fluid*, by which alone the electric matter ſeems to be carried from one body to another. The reſemblance between the hygroſcopic and electrical phenomena are affirmed to be*,

1. As watery vapour or ſteam is compoſed of fire, the deferent fluid, and water, the gravitating part, ſo *electric fluid* is compoſed of the *electric deferent fluid*, and *electric matter*.

2. As *vapours* are partly decompoſed when too denſe for their temperature, and then their *deferent fluid* becomes free, and ſhews itſelf as *fire;* ſo *electric fluid* that is too denſe is decompoſed, and its *deferent fluid* manifeſts itſelf in the *phoſphoric* and *fiery* phenomena of *electricity*.

3. As *fire* quits the *water* of *vapour*, to unite itſelf with a body leſs warm; ſo the *electric deferent* quits the *electric matter*, in part, to go to other bodies which have proportionally leſs of it.

In this analogy, however, there is a diſtinction. *Fire*, in quitting the *water* in *vapour*, remains actuated by nothing but its expanſive force; remains free, and extends itſelf till the equilibrium of temperature is reſtored; but the *electric deferent*, when diſengaged from *electric matter*, in order to reſtore its peculiar equilibrium, is actuated by *tendencies* to diſtinct bodies, and acts by this *tendency* in thus reſtoring the *electric equilibrium;* and it is only in conſequence of this *tendency* that it quitted the *electric matter*. This *tendency* is then directed to ſome body in the vicinity.

4. As the *fire* of *vapour* pervades all bodies, to reſtore the *equilibrium of temperature*, depoſiting the *water;* ſo the *electric deferent* quits the *electric matter*, to reſtore the *electric equilibrium* in an inſtant, and for this purpoſe pervades all bodies, depoſiting on them the *electric matter* which it carried, but differently, according to their natures.

5. As *fire* and *water*, while compoſing *vapour*, retain their *tendencies* and *affinities* by which they produce the *hygroſcopic* phenomena; ſo the ingredients of the *electric fluid*, even in their ſtate of union, retain their *tendencies* and *affinities*, which produce the greateſt part of the *electric phenomena*.

6. In particular, the *electric matter* retains its *tendencies* and *affinities;* and farther, the *electric affinities* are, like the *hygroſcopic*, without any choice.

Here, however, there is a farther diſtinction. The affinities of *water* reſpect only *hygroſcopic* ſubſtances; but thoſe of *electric matter* reſpect all ſubſtances, and therefore reſpect the common atmoſpheric fluids.

7. When *fire* quits the *water* of *vapour*, to form the *equilibrium of temperature*, it remains in the place where *vapour* moſt abounds, but is partly *latent*, not exerting its powers; ſo in the reſtoration of the equilibrium of the *electric deferent* among neighbouring bodies, thoſe which have proportionally moſt *electric matter* alſo retain moſt *deferent fluid*, but in a *latent* ſtate.

8. As two maſſes of *vapour* may be in *expanſive equilibrium* (which others call balancing each others elaſticity) although the *vapours* contain very different proportions of *fire* and *water;* ſo two maſſes of *electric fluid* may be in *expanſive equilibrium*, although one contains much more *electric matter* in the ſame bulk, provided that the *electric deferent* be alſo more copious.

The chief diſtinction that mingles with theſe analogies is, that the *affinity* of *water* to *hygroſcopic* ſubſtances operates only in contact, whereas *electric matter* tends to diſtant bodies; and theſe diſtances are very different in regard to different bodies.

Such is the reſemblance which has appeared ſo ſtrong to Mr de Luc. It is evidently the ſame which furniſhed the conjecture to Mr Ruſſel, and which he conſidered mechanically, in order to explain the phenomena of electric motions to ſtudents of mechanical philoſophy. The only reſemblance ſeems to us to appear in the condenſation of moiſture contained in damp air.

Mr de Luc, led by the habits of his former ſtudies, attempts to explain every thing by the relations which were moſt familiar to him, *affinities* and *expanſive forces*. Let us attend a little to the manner in which he explains one or two of the moſt general facts.

1. *The conditions of conductors and non-conductors.* 230

This diſtinction depends on the differences in the *tendency* to diſtant bodies: there are great differences in theſe diſtances according to the nature of the bodies; and from this ariſe great differences of phenomena, independent of inſulation or non-inſulation, which are only the ſenſible diſtinctions of theſe claſſes of bodies.

Electric

* See *Idées ſur la Meteorologie*, § 266, &c.

Electric matter tends to *conductors* at great diſtances ; but having reached them, it does not adhere, and remains free to move round them, being dragged by the *deferent fluid* ; but its tendency to *non-conductors* is only at ſmall and inſenſible diſtances ; and having come into contact, it adheres, and can no longer be dragged by the *deferent fluid*.

Hence the operation of *conductors* and *non-conductors* ; and there is no other foundation for the notion of *idio-electrics* and *non-electrics*, or electrics by communication. A part of a *non-conductor* takes as much *electric matter* as it can from the ſubſtance furniſhing it ; but cannot communicate it to another part, except very ſlowly ; therefore, to communicate it to the whole ſurface, we muſt cover it with a conductor (Surely this is a diſtinction in the body, independent of the diſtance of mutual tendency !).

Hence, too, the property of *non-conductors* by which the electric fluid is *benumbed* (*engourdi*) or cramped ; therefore we can accumulate a great deal in them ; and it will remain long, being *benumbed* ; and if it be determined to quit them at once, the current will be much more denſe than when quitting an equal conducting ſurface.

Since *conductors* do not fix the *electric fluid*, it *muſt circulate round them*. It is urged to this motion by its *expanſive power*, by which it would diſperſe from a body with inconceivable velocity, and perhaps the rapidity of its motion would decompoſe it, and cauſe ſome *light* to emerge ; but it is at the ſame time impelled by its *tendency* to bodies. Thus, by theſe two forces, it runs to a *conducting body*, and muſt circulate round it as the planets do round the ſun. In this circulation, if it come to any great projection, it cannot follow the outline, becauſe ſo abrupt ; it therefore flies off at all points and protuberances. It will be the more difficult to keep to an abrupt outline as the ſtratum in circulation is more copious or deeper, becauſe a greater maſs is with greater difficulty turned round a ſharp angle. It is more inclined to eſcape if another body be near, and it immediately becomes a ſatellite to that body.

Thus all bodies get a ſhare of electric fluid, circulating round conductors, and *benumbed* or *cramped* in *non-conductors*. Bodies of this laſt claſs receive their portion by the air as *hygroſcopic ſubſtances* receive their water by the *fire*.

All the differences in the tendencies to bodies proceed from the *electric matter*. The *deferent fluid* follows other laws ; namely, 1. Its tendency to all ſubſtances is greater than that of the *electric matter* to any one. 2. The tendency (and alſo that of the *electric matter*) is always from the body which contains moſt of it to that which contains leaſt. 3. The body which contains moſt of the one alſo contains moſt of the other. 4. The *deferent fluid* has a particular affinity (chemical) with the *electric matter*. 5. All theſe tendencies are leſſened by an increaſe of diſtance. 6. the *electric matter*, when compoſing *electric fluid*, has more or leſs *expanſive force* as it is united to more or leſs *deferent fluid*.

Explanation of Charged Plates.

231 Mr de Luc ſays (§ 286.), that his System was ſuggeſted by Volta's *Theory of Electric Influences*. Theſe (ſays he) had been pretty well generaliſed before, but with little improvement to the ſcience, till Mr Volta diſcovered a circumſtance which, in his opinion, connected by a general theory many phenomena which had formerly no obſerved relation to any thing. This was, that *when a body electrified poſitively brings a neighbouring body communicating with the ground into the negative ſtate, its own poſitive electricity is weakened while it remains in that neighbourhood, but is recovered when the other body is removed.* “ Such is the diſtinguiſhing law of Mr Volta's theory, which brings all the phenomena of electric influences under his theory, beginning with thoſe of coated glaſs, which were formerly ſo obſcure, becauſe they were not referred to their true cauſe, &c.

“ My System (Mr de Luc ſays) concerning the nature of the *electric fluid* explains the laws of Mr Volta's theory ; and of conſequence explains, like it, all the phenomena which it comprehends : but it reaches much farther, ſeeing that more general laws comprehend a greater number of phenomena.

“ In the phenomena of coated glaſs, I plainly ſaw one of the procedures of *watery vapour*. Suppoſe a glaſs pane, moiſtened on both ſides, and having the temperature of the ſurrounding bodies. Suppoſe that warmer *vapour* comes to one ſide. It is condenſed on the ſurface ; that is, it is decompoſed, the *water* adheres to the ſurface, and the *fire* penetrates the glaſs, heats it, and increaſes the evaporation from the other ſide, by entering into combination with the *water*, and carrying it off with it. More *vapour* is condenſed on the ſide A ; more *fire* reaches the ſide B, and carries off more *water*. But as this happens only becauſe the *fire* alſo raiſes the *temperature* of the pane, it is evident that the condenſation on the ſide A, and the evaporation from B, muſt gradually ſlacken, and the *maximum of accumulation* in A, and of evaporation from B, will take place when the temperature of the pane is the ſame with that of the hot *vapour*.

“ The electrical phenomena of coated glaſs are perfectly ſimilar. The *electric fluid* reaches the ſide A, is decompoſed, and the *electric matter* is there *benumbed* and fixed. The *deferent fluid* penetrates the pane, and carries off the *electric matter* from the ſide B. This goes on, but ſlackens ; and the maximum of accumulation and evacuation obtains when the ſide A has acquired the ſame intenſity of electricity with the charging machine. More is accumulated in A than is abſtracted from B : becauſe B is farther from the ſource (he might have added, that part of the fire is expended in raiſing the temperature of the pane) : but the accumulation is inactive, becauſe the *electric matter* is *benumbed* and fixed. Though the *electric matter* is much diminiſhed in B, yet the *electric fluid* in its coating has as much expanſive force as that of the ground ; becauſe it has a ſurplus of deferent fluid. The abſolute quantity of *electric matter* in both ſides is ſomewhat augmented.”

232 This explanation of the Leyden phial comprehends the whole of Mr de Luc's theory ; and the conſtitution of the electric fluid, and its various affinities, expanſive powers and tendencies, are all aſſigned to it in ſubſerviency to this explanation, or deduced from thoſe phenomena. As the author, in all his writings, claims ſome ſuperiority over other naturaliſts for more general and comprehenſive views, and for more ſcrupulous attention to preciſion and meaſurement, and particularly for more ſolicitude that no natural agent be omitted

that has any ſhare in the procedure,—he ſurely will not be offended, although we ſhould ſtate ſuch difficulties and objections as occur to us in the conſideration of this SYSTEM (as he chooſes to call it) of electricity.

We wiſh that it had been expreſſed in the plain and preciſe language of mechanical and chemical ſcience; for he reaſons entirely from the nature of expanſive forces, tendencies, and affinities. His language will appear to ſome readers, as it does to us, rather to expreſs the conduct of intelligent beings, acting with choice, and for a purpoſe, than the laws of lifeleſs matter. His account would have been leſs agreeable, it is true, but more inſtructive, and leſs apt to be miſtaken. Metaphorical language is ſeldom uſed without the riſk of metaphorical conceptions; and the reader is very apt to think that he has acquired a notion of the ſubject, while he is really thinking of a thing of a different nature. We apprehend that a great deal of this happens in this inſtance, and that when the narration is ſtripped of its figurative language, it will be found without that connection and analogy which it ſeems to poſſeſs.

We alſo wiſh that the explanation had been derived from ſome well eſtabliſhed principle. The whole of it is *profeſſedly* founded on a reſemblance between the *phenomena* of electricity and ſome things ſaid of watery vapour; but theſe are not the *phenomena* of watery vapour, but Mr de Luc's *hypotheſis* (he will pardon us the term, which we prefer to *ſyſtem*) concerning *watery vapours*. We do not think it philoſophical to explain one hypotheſis by another. Our illuſtrious countrymen Bacon and Newton, diſapproved of this practice; and their rules of philoſophiſing have ſtill currency among philoſophers. Explanation, in our opinion, is the pointing out ſome acknowledged general fact in nature, and ſhewing that the particular phenomenon is an example of it. We do not ſee this in Mr de Luc's explanation; becauſe we do not ſee the *facts* in the caſe of watery vapours to which the *phenomena* of electricity are ſaid to have a reſemblance. The phenomena we mean are chiefly the *motions*, and the *transferences* of the powers producing ſuch motions; we do not ſpeak of the *light*, and ſome other phenomena, becauſe Mr de Luc does not ſpeak of them in this explanation. We ſhall even admit the *transference* as a *phenomenon*, although we do not ſee any ſubſtance transferred: but we ſee a power of producing certain motions, where that power did not formerly appear; and the appearance of this power is all the authority adduced, even by Mr de Luc, for the transference. We muſt now add, that the electric phenomena, which Mr de Luc calls like the phenomena of watery vapour, are all *ſuppoſitions*; and that therefore the explanation is a ſyſtem of ſuppoſitions, *framed* ſo as to be like the ſyſtem of watery vapour. For Mr de Luc will grant, that, on the one hand, we ſee nothing like the water in the electric phenomena; and, on the other hand, there is nothing in watery vapour like the motions of the electrometers, which are the only PHENOMENA from which Mr de Luc profeſſes to reaſon.

We alſo fear that the very curious experiments of Count Rumford on the melting of ice, and the propagation of heat through liquids, will oblige Mr de Luc to change the taſks of the ingredients, both of *vapour* and of *electric* fluid. *Water*, and not *fire*, ſeems to be the *carrier* or *deferent fluid;* and we think that Franklin and Æpinus have made it highly probable that electricity, and not air, is the carrier.

We have alſo great difficulty in conceiving (indeed we cannot conceive) how the *deferent fluid*, from which the *electric matter* has been detached by its ſuperior *affinity* with the ſide A, can overcome the *ſame ſuperior affinity* of the *electric matter* with the ſide B (A), and carry it off: how the *deferent fluid* penetrates the non-conducting pane, in order to carry off the *electric matter* in the form of *fluid;* and how it cannot do this, except by means of a *conducting canal*, into which *it is expreſsly ſaid that it does not penetrate*. It muſt not be ſaid that it runs along the ſurface of this canal: for the ſmalleſt wire will be a ſufficient conductor, covered a foot thick with ſealing-wax. This indeed, according to Mr de Luc, allows the deferent *fluid* to paſs; but it muſt alſo, according to him, ſtrain it pretty clear of all *electric matter*. For we cannot help thinking, that the proceſs (although purely ideal) has a cloſer reſemblance to what we ſhould obſerve in a ſtream of muddy water poured on a ſtrainer, both ſides of which are previouſly foul. If we were diſpoſed to amuſe ourſelves with a figurative hypotheſis, we could give one on the principle of filtration that is very pretty, and pat to the purpoſe, of glaſs coated, and charged and diſcharged by conducting canals.

With reſpect to the ſuggeſtion of this theory by Volta's theory of electric influences, and the ignorance of naturaliſts before that time of the true ſtate of things, we muſt obſerve, that Mr Ruſſel propoſed the ſame analogy to the conſideration of his hearers many years before; and it was very generally known. The electric influences had been fully detailed by Æpinus and Wilcke in 1759, and applied with peculiar addreſs and force of evidence by Mr Cavendiſh before 1771; and they were deſcribed nearly in the ſame way by Lane, Lichtenberg, and others.

And with reſpect to Mr Volta's general principle, which Mr de Luc prizes ſo highly, and by which he explains every thing, we muſt obſerve, that *it is not true as a phenomenon in electricity;* but, on the contrary, *the poſitive ſtate of a body is rendered ſtronger, or more remarkable, by inducing the negative ſtate on a neighbouring body.* See n° 52. and 66. Mr Volta was miſled by the appearances of the electrophorus, which had engaged all his attention, and modelled all his notions on theſe ſubjects. His obſervations had been confined to diſks; and though theſe are excellent inſtruments for producing very ſenſible effects, they are quite unfit for examining the general nature of electric influences. Even without much knowledge of dynamics, a perſon muſt perceive that the action of their different parts on the electrometer may be very different, by reaſon of their different poſitions and diſtances from it. Beſides the electrometers of the apparatus deſcribed by Mr de Luc in ſect. 440. &c. *did not* indicate the real condition of the diſks to which they were attached, but the condition of the remote

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(A) We may here aſk, How comes there to be ſuch a quantity of electric matter already lodged in B?—Is it benumbed? or in what ſtate is it?

remote ends of overcharged conductors of conſiderable length. Therefore, although all the electrometers fell lower when the other group of diſks was brought near, the poſitive ſtate of the neareſt diſk was greatly augmented. The moſt unexceptionable apparatus for this purpoſe would be a row of poliſhed balls on inſulating ſtands, placed in contact, the whole charged poſitive; and when another ſuch group, or a long body, is brought near, let the balls be ſeparated at once, and examined apart by a very ſmall electrometer, made in the form of our figure 8. We preſume to ſay that, if the other group is properly managed, and made to communicate thoroughly with the ground, the poſitive electricity of the balls neareſt to it will be found greatly augmented, and that every one of them will be found in that preciſe ſtate of electrification that is pointed out by the Æpinian theory. Mr de Luc has made and narrated the experiments with the diſks, and the curious figures obſerved by Lichtenbergh, with great judgment and fidelity; and they are claſſical and valuable experiments for the examination of the theory. We may here mention a very neat way of executing the apparatus of balls, which was practiſed by a young friend who was ſo kind as to make the experiments for us, when our thoughts were turned to Mr de Luc's theory. Each ball was mounted on a ſlender glaſs rod varniſhed. The lower end of the ſtalk was fixed in a little block of wood which had a ſquare hole through it, by which it ſlided ſteadily along a horizontal bar of mahogany, ſupported at the ends about an inch from the table. The balls were made to ſeparate at once, and equally, from each other, by a chequer-jointed frame, ſuch as is ſeen in the toy-ſhops, carrying a company of foot ſoldiers, who open and cloſe their ranks and files by pulling or puſhing the ends of the frame. Taking out the pins of the middle joints of this checquered frame-work, and widening the holes for receiving the glaſs ſtalks, it is plain, that all the balls will ſeparate at once, in the very ſtate of electricity in which they were when in the neighbourhood of the non-inſulated group. This apparatus conſiſted of ſix balls. We found the ball next the other group much more ſtrongly poſitive than before bringing that group near, and it was generally the third ball which ſeemed equally electric in both ſituations. We added nine balls more, connecting the whole by a ſimilar contrivance, and found it a moſt inſtructive apparatus for the theory of the diſtribution of the electric fluid. We wiſh that it had occurred to us when the n° 62. &c. were under conſideration.

With reſpect to the condition in which the electric matter is ſaid to be lodged in the ſide A of the coated pane, where Mr de Luc ſays that it is fixed, *(engourdi)*, in the *non conducting ſurface* (which condition Mr de Luc conſiders as characteriſtic of ſuch ſubſtances), we muſt ſay that the deſcription of its ſtate is by no means agreeable to what we have obſerved. The powers of this *electric matter* are no more *benumbed* or enervated (it is a very unphiloſophical phraſe), than if it were in a *conducting* body at the ſame diſtance from the oppoſite coating. If coatings be applied to a block of glaſs of two or three inches in thickneſs, and if the electrification be ſo moderate that it would not fly from the one coating to the other when the glaſs is removed—no ſenſible difference will be found between the electricity of the two coatings with or without the glaſs. The electric matter in the ſide A has not its powers *engourdi;* they are *balanced* by the powers of the ſide B.

But how will Mr de Luc explain the charging a pane negatively? How will he bring off a quantity of *electric matter*, greater (according to his own account) than what will be *benumbed* on the other ſide? Nay, we muſt aſk, where does he find it? Is there a quantity already *benumbed* there? What is to revive it?

Let us now conſider a little the conſtitution of the ingredients of this electric fluid, by which all theſe things are brought about. And in doing this, let us baniſh, when poſſible, all figurative language; and, in the preciſe and dry phraſeology of dynamics, let us ſpeak of the motion of ſingle particles of the *electric fluid, deferent fluid,* and *electric matter.* By *expanſive power*, muſt certainly be meant ſuch a power as that by which air, gaſes, inflamed gunpowder, ſteam, and the like, enlarge their bulk, and which is clearly manifeſted as a mechanical preſſure, by burſting veſſels, impelling bullets or piſtons, &c. as well as by the actual enlargement of the bulk of the fluid. We have no other indications of its being a *force;* and therefore our notions of its mode of acting muſt be derived ſolely from what we *underſtand* of this power in air or the other fluids. Newton's *Principia* are our authority for ſaying, that all that we know of it is, that it acts as a number of corpuſcles would act, which repel each other with a force inverſely proportional to their diſtances; this action not extending beyond the adjoining corpuſcle, not even to the ſecond. We know a good deal of the propagation of preſſure and progreſſive motion through ſuch a fluid, when it is confined in a veſſel or ſyſtem of veſſels, of any form, and ſome few ſimple circumſtances which take place in the elaſtic undulations which may be excited and propagated through it. We have but a *very indiſtinct notion* of the motions which one maſs of ſuch a fluid will produce in another maſs, when both are at liberty to expand. This is very indiſtinct; but we are certain that it will be like the motion of two maſſes of air blown or driven againſt each other. Now theſe electric fluids, by their expanſive powers, muſt act like thoſe others with which we are more familiarly acquainted. And here we venture to ſay, that the appearances in electricity are ſo far from being like theſe, that we cannot imagine any thing more remarkably different. We ſhall mention but one thing. Every mark that we have for the preſence of *electric fluid* obliges us to grant, that in an overcharged body it is crowded into the external ſurface, ſo that the quantity has little or no relation to the quantity of matter in any body, but merely to its ſurface. This is quite unlike air, or any other expanſive fluid, which is uniformly diſtributed through the whole ſpace comprehended by the ſurface which bounds it. We never ſaw any thing like ſtreams of this *electric fluid*, impelling, or any way acting on each other, except in the transference by ſparks; and there it was indeed like the motions of air, for it was not *electric fluid*, nor *electric matter*, but *electrified air.*

Let us next conſider the *tendencies* by which the relations of theſe expanſive fluids to other bodies are produced, and the electric motions are ſaid to be explained. We obſerve that Mr de Luc avoids the uſe of the words *attraction* and *repulſion*, ſo much employed by the Britiſh philoſophers. He conſiders theſe tendencies as determinate impulſions, and adopts the doctrine of *Le*

Sage of Geneva, who has not only laid Newton under great obligations, by a mechanical explanation of gravity, but has alſo explained expanſion, elaſticity, chemical affinity, and all ſpecific tendencies, to the ſatiſfaction of the moſt eminent mathematicians. To ſuch only Mr de Luc profeſſes to addreſs himſelf, who are not contented with a doctrine which ſuppoſes bodies to act where they are not. But, unfortunately, Mr le Sage has never obliged the world with this explanation. We are not moſt eminent mathematicians; but we are able to prove, that Mr le Sage's favourite theorem, mentioned by Mr de Luc in §157, 158, as demonſtrated by Mr Prevoſt, the editor of *Lucrece Neutonien*, is a complete dereliction of the firſt principles of Mr le Sage, and is alſo incompatible with mechanical laws. Mr de Luc ſhould have given a demonſtration of the theorem on which all his ſyſtem reſted; otherwiſe it is only reviving "*dixit philoſophus, ergo verum.*"

But let us ſee what theſe tendencies perform. Mr de Luc ſays, that the fluid, ſetting out from a body by its expanſive power, would move in a ſtraight line with inconceivable velocity, and would immediately deſert even this globe, were it not deflected by its tendency to other bodies. We do not ſee whence this immenſe velocity is derived. But let it go off; it is deflected from its rectilineal courſe by its tendency to ſome conducting body, which it reaches, but cannot or does not enter; and therefore *muſt continually circulate round it, as the planets circulate round the ſun*, following its outline, if not too abrupt, but flying off from all points in the direction of the axis of the point, &c. Here we are at home, for this is a plain dynamical problem of central forces. All that we ſhall ſay on this head is, that Mr de Luc has certainly not conſidered the planetary motions with attention, when he hazarded this very comprehenſive propoſition. If he will take the trouble to do this, he will ſee that every part of it is inconſiſtent with the acknowledged laws of mechaniſm, and that the motions are abſolutely impoſſible. Beſides, we know that it will not fly off from a hundred points placed together, which is a ſtill more abrupt outline, if they do not project beyond the brim of a pit in which they ſtand; yet this pit only makes the outline more abrupt. We farther believe, that no perſon can form to himſelf any diſtinct notion of ſuch circulations round every conducting body; they will be more numerous, and infinitely more confuſed and jarring, than all the vortices of Des Cartes. How can ſuch motions take place round a bunch of braſs wire buried in ſealing-wax? Yet he muſt grant that they really happen there? or what prevents the *electric fluid* from being *ſtrained* clear of all electric matter in paſſing thro' the air?

We would alſo aſk, why the tendency is always *from the body containing moſt of the fluid to that containing leaſt?* It is not enough to ſay that it is ſo; this would only be contriving a thing to ſuit a purpoſe; a reaſon ſhould be given if we pretend to explain. Now the tendency to a diſtant body *is to the matter* in that body, without any relation to the fluid in it, or in the body from which it came.

On the whole, we cannot think this theory is any thing but telling a ſtory of ideal beings, in very figurative language, which gives it ſome animation and intereſt. The different affinities, tendencies, and powers, are only ways of expreſſing certain *ſuppoſed* events, and ſuited to thoſe events; but it gives no explanation of the *obſerved mechanical phenomena* of electricity, ſhewing from acknowledged principles that they muſt be ſo.

What a difference between this laboured and intricate mechaniſm, and the ſimple, perſpicuous and diſtinct theory of Æpinus! Even Mr Ruſſel's explanation is more intelligible, and more applicable to the *motions* which are really obſerved. That gentleman ſaw the neceſſity of conſidering them as the ſubjects of *mechanical diſcuſſion*, and that all that was wanted was to find out what law of diſtant action would tally with the phenomena. The Scotch philoſopher was careful to warn his hearers that he only propoſed a *conjecture*. The Swede calls his performance *Tentamen Theoriæ*, &c. and begins and concludes it with expreſsly ſaying, that it is only a *hypotheſis*. The Engliſh nobleman calls his diſſertation an *Attempt* to explain ſome of the phenomena, &c. None of theſe philoſophers call their works a SYSTEM, which comprehends all theories, whether that of Volta, or of any other ſucceſsful inquirer.

We hope to be excuſed for treating ſo largely of this ſubject. It ſtruck us as a very proper example of the bad conſequences of indulging in figurative language. It muſt be very ſeducing, when ſo ſcrupulous and ſo eminent a philoſopher as Mr de Luc is led aſtray by it.

WE conclude this long article by obſerving, that whatever may be the fate of Mr Æpinus's *hypothetical theory*, his claſſification of the facts, and his preciſe determination of the *mechanical phenomena* to be expected from any propoſed ſituation and condition of the ſubſtances, will ever remain, and be an unerring direction in future experiments; and the whole is an illuſtrious ſpecimen of ingenuity, addreſs and good reaſoning. We hope to make this ſtill more evident, when we apply it to the quiet and manageable phenomena of MAGNETISM 233

Pondere et menſurâ.

APPENDIX;

CONTAINING AN ABSTRACT OF MR COULOMB'S EXPERIMENTS.

MR COULOMB in the *Mem. de l'Acad. de Paris* for 1786, relates ſeveral experiments made for aſcertaining the diſpoſition or diſtribution of the electric fluid in an overcharged body. Their general reſults were,

1. That the fluid is diſtributed among bodies according to their figure, without any elective affinity to any kind of ſubſtance.

For when a ball, or body of conducting matter, and of any ſhape, is electrified to any particular degree, as indicated by his electrometer, if it be touched by another equal and ſimilar body, ſimilarly ſituated in reſpect of the touching points, the electricity is always reduced to $\frac{1}{2}$.

2. In an overcharged conducting body, the fluid diffuſes itſelf entirely along the ſurface, without penetrating into the interior parts.

The conducting body AB (fig. 37.) had pits *a*, *b*, &c. made in various parts of its ſurface. They were half an inch in diameter, and ſome of them $\frac{1}{10}$th, others, $\frac{2}{10}$ths, others $\frac{3}{10}$ths, &c. in depth. *c* repreſents the edge of a ſmall circle of gilt paper, $\frac{1}{5}$th of an inch in diameter, fixed perpendicularly on the end of a fine thread

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